THE

JOURNAL OF GEOLOGY

JULY-AUGUST, 1898

THE ULTERIOR BASIS OF TIME DIVISIONS AND THE CLASSIFICATION OF GEOLOGIC HISTORY.

It was intimated in the introduction to the symposium on the classification and nomenclature of geologic time divisions published in the last number of this magazine that the ulterior basis of classification and nomenclature must be dependent on the existence or absence of natural divisions resulting from simultaneous phases of action of world-wide extent. If there have been such universal phases and if they can be detected, they must ultimately be accepted not only as the true basis of division, classification and nomenclature, but their exposition must constitute the major work of research and of instruction. The most vital problem before the general geologist today is the question whether the earth's history is naturally divided into periodic phases of world-wide prevalence, or whether it is but an aggregation of local events dependent upon local conditions uncontrolled by overmastering agencies of universal dominance.

That there were no universal breaks in sedimentation or in the fundamental continuity of life is not only admitted but affirmed without hesitation. The old doctrine of physical cataclysms attended by universal destruction of life has passed beyond serious consideration. And so, in the judgment of the writer, have all doctrines which attribute profound effects on the life of the globe or the progress of sedimentation to the violence of physical disturbances of any kind. That sedimentation has

been in constant progress somewhere since the inauguration of the pre-Cambrian lands and seas, and that life has been likewise continuous and self-derivative, may be accepted as fundamental postulates. If, therefore, we seek for *absolute* divisions we doubtless seek in vain. But this does not dismiss the question whether this continuity of physical and vital action proceeded by heterogeneous impulses or by correlated pulsations. If the latter, then the history of the earth, when deciphered, will assume a rhythmical periodicity susceptible of natural classification and of significant and rational nomenclature; if the former, the contradictory phases of local actions will inhibit all but the most general unity and render classification and nomenclature either arbitrary or provincial.

I venture to urge three general grounds upon which I entertain the former view. These grounds, if valid, hold out the hope that the history of the earth will be found not only susceptible to natural division, but capable of its truest exposition only through the recognition of its inherent periods.

I. The first of these grounds is the presumption that great earth movements affect all quarters of the globe. Minor stresses may find relief in local readjustment, but profound stresses cannot be relieved, it is assumed, without generating appreciable stresses in other portions of the globe and leading to general readjustment. In a globe, all of whose parts owe their positions to the stress and tension of other parts, every rearrangement that rises in magnitude above the limits of local support extends its influence to the whole. Any massive earth movement must change the gravitative stresses of all parts of the globe unless the movement be divided into contrary phases so adjusted as to be compensatory, the possibility of which in the strict sense may be questioned. The recognized causes of profound movements such as secular refrigeration, change of speed of rotation, progressive molecular rearrangement, and like agencies, are comprehensive in their action and accumulate general stresses whose natural issue is coöperation in a common movement of relief.

The validity of this presumption of general coöperative movements will perhaps not be so much questioned as the mode of their execution. There are those who believe that a downward movement in one region is correlated with an upward movement in some other region. The correlated movements have, therefore, opposite phases and if the distribution of these is not controlled by some unifying agency the general terrestrial effects are heterogeneous, or, if not that, at least uncertain. This view is the natural sequence of the doctrine of a thin, floating crust warping to satisfy its own changes of density and tension, and wrinkling to adapt itself to a shrinking nucleus. Accepting the truth that lies under this view, but rising to a broader generalization, there are those who entertain the conception that the depressions of the earth's surface habitually became more depressed with every readjustment to smaller dimensions (local exceptions aside), while the protuberances became more protuberant. In other words, the oceanic basins became progressively deeper and more capacious, while the continents became higher (degradation aside). In this assumption of habitual downward movements of the ocean bottoms and of correlative upward movements of the continents, there lies, if it be true, a basis for the natural division of geologic events, these movements being in themselves and in their immediate consequences the basis of such division. The full establishment or overthrow of this assumption must await the extension of critical research to at least the major part of the earth, and it is not the purpose of this paper to seriously attempt its advocacy by the citation of the evidence already gathered in its support. Incidentally it will be touched upon in the discussion following.

II. The second ground of belief in a fundamental periodicity in terrestrial progress is founded on the conviction that the major movements of the earth's surface have consisted of the sinking of the ocean bottoms and the withdrawal of additional waters into the basins whose capacities were thereby increased. This belief is not quite identical with the assumption last made, for it does not necessarily involve the simultaneous action of

the different ocean beds, although the conclusions about to be urged would be strengthened if such common action could be demonstrated. But quite apart from this, it is believed the following argument rests upon rather firm observational and inductive grounds except in the matter of two fundamental postulates which are almost universally assumed by geologists. These are as follows: (1) It is assumed that the earth was at first a nearly perfect spheroid, the surface being essentially plane. (2) It is assumed that the great movements of the earth's crust have consisted fundamentally of shrinkage. Probably no serious geologist maintains that the earth has enlarged its average diameter during geological history by expansive action, whatever he may hold respecting local expansion.

These two propositions being accepted, it follows that the radial shrinkage of the ocean bottoms has surpassed the radial shrinkage of the continental platforms to the average amount of some 10,000 or 12,000 feet. This excess of radial shrinkage is to be multiplied by four to measure the excess of volumetric shrinkage, since the area of the ocean bottoms is about four times the area of the continental platforms. The master factor, therefore, in the surface movements of the earth has been the sinking of the ocean bottoms and the formation of the great oceanic basins. Most geologists will probably agree that the continental platforms have also sunk, in the sense that they have shortened their radial distances from the center of the earth. Opinion seems to be divided, however, on the question whether there have been actual epeirogenic uplifts or not. Probably most geologists would regard the rising of the Thibetan plateau in late Tertiary times as involving an actual increase of radial distance. Probably very few geologists would question the absolute elevation of the crests of the loftier mountain ranges. However, the question of absolute as distinguished from relative sinking does not seriously affect the question in hand. If the earth has absolutely grown smaller by some notable amount the average ideal ocean has, as a consequence, grown deeper (if its volume has remained constant), for its circumferential expanse

has been reduced. Aside from this, so far as I can see, our argument holds as firmly for relative as for absolute sinking.

From the greater depths to which the ocean bottoms have sunk, the presumption follows that in every great crustal readjustment the major factor consisted of the descent of the ocean bottom or some part of it. Logically, as here stated, this is only a presumption which might be set aside by the assumption of a single or a few great depressions, while the other movements might be upward or indifferent, but this will appear less tenable in the light of further considerations.

Not only has there been increase in depth, but increase in capacity also. From a capacity essentially zero at the outset the basins have developed a capacity sufficient to hold nearly all the water of the globe. In the aggregate, therefore, the capacities of the ocean basins, as well as their depths, have been increased by crustal readjustment, and the presumption is that this has usually been the case in individual readjustments, although this does not rigorously follow. It will be sustained, however, by further considerations. The crustal readjustments here referred to are those resulting from internal causes. External readjustments work to precisely opposite ends, the degradation of the land and the filling of the basins. This opposing action strengthens the presumption that the internal causes have habitually increased the capacity of the basins, for they have grown more and more capacious in spite of this constantly opposing action. This constant filling in affords a presumption of frequently repeated increases of capacity; otherwise the land should have disappeared.

Proceeding upon the presumption that internal readjustments habitually increased the capacity of the ocean basins, it is important to note in detail the consequences that follow. These are involved in the functions of the circumcontinental terrace, and will be more easily followed after an explicit statement of these functions. These are more or less fully apprehended by all acute students of continental evolution, but like the correlative functions of baseleveling previous to the explicit exposition

of Powell, they have not come into that large service as working principles of which they are susceptible.

Every continent which stands in a given position with reference to the sea for any prolonged period develops a submarine terrace about its borders. This is formed from the débris of the land deposited beneath the edge of the sea. In its initial stages it is nothing more than the familiar shore terrace; but as it develops it becomes a broad submerged platform with a steep face dropping away to the abysmal depths of the ocean. The submerged platform has its outer limit at the depth at which detritus can be effectively moved off shore by the agitation of the surface waters. This, though varying with conditions, may be roughly taken to be one hundred fathoms. The breadth attained by the upper surface of the terrace is conditioned upon the length of time the continent remains in a fixed attitude and the activity of land wash. Simultaneously the sea cliffs are moving inland, and the valleys are developing base plains which are the correlatives of the terrace plain which is growing seaward, as illustrated in Fig. 1.

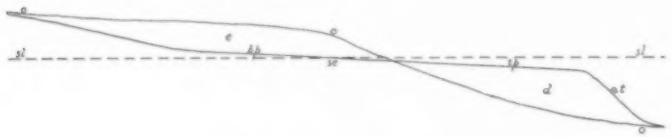


FIG. 1.—*o-o* Original surface. *s l* Sea level. *e* Land carried away by erosion. *d* Detritus built into circumcontinental terrace. *t p* Terrace plain. *a t* Abysmal terrace face. *b p* Base-plain developing landward.

The extreme limit of development is attained when the continent has been baseleveled and no farther detritus is furnished for the extension of the terrace. The baselevel of the continent then becomes essentially continuous with the submerged terrace surface, and the whole constitutes the perfected continental platform, as shown in Fig. 2.

The development of the circumcontinental terrace and of the perfected continental platform is subject to intercurrent disturb-

ances from local and from general sources. There appear to be two systematic sources of slight but very critical modification that require special consideration.

FIG. 2.—*b p* Continental base-plain. *s l* Sea level. *t p* Submerged terrace plain. *a t* Abysmal terrace face.

1. The transfer of débris from the land to the sea displaces an equivalent amount of water, and raises the sea level proportionately, and causes an advance upon the land. The effects are volumetrically small compared with the great body of the ocean, but a slight rise in the surface as the baselevel stages of the continent are attained is peculiarly effective. This coöperates with the cutting back of the sea cliff, and, combined, they become effective in advancing the edge of the sea upon the border of the land.

2. There are both theoretical and observational grounds for the belief that in the process of periodic readjustment of the earth to its internal stresses, portions of the crust are thrust up to heights notably above the plane of isostatic equilibrium, and that these portions gradually settle back toward equilibrium by virtue of the slow fluency or quasi-fluency of the rocks. Recent pendulum studies by Putnam and Gilbert seem to indicate that the portion of our continent most notably lifted in late Tertiary times still stands appreciably above isostatic equilibrium, and there is little doubt that the same is true of other continents, as is, indeed, indicated by partial pendulum data. There is, however, a large mass of concurrent data which shows an aggregate subsidence of the continent since late Tertiary times, data which have been industriously marshaled in the interests of an epeirogenic explanation of the glacial period. This leads to the impression that in late Tertiary times, when the upward move-

ment reached its maximum effects, the land stood very notably above isostatic equilibrium, and that it has been settling back, but has not even now reached isostatic equilibrium. While the generalization cannot be rigorously established, there seem to be sufficient data to warrant entertaining tentatively the doctrine that in periods following crustal upheavals which pass beyond the plane of equilibrium the lifted portions slowly settle back toward equilibrium. If so, this retrocession would coöperate with the filling of the basins in causing an advance of the sea upon the land. At the same time the conditjons for the seaward growth of the terrace plain may still continue and the plain be thus simultaneously extended on both borders.

As already noted, the evolution of this peri-coastal plain is subject to interruptions and local modifications to an extent comparable to the interferences in the development of a base-plain, and perhaps to a greater degree, but I think it has like claims to acceptance as an effective general process.

Now the development of such submerged terraces around the several continents for any given period is accurately correlated by the sea level. They are all built immediately beneath its border at a common level. The continental baselevels are correlated by the same controlling horizon. So, necessarily, the final continental platforms are likewise reduced to the same common natural datum plane.

If, therefore, it be admitted that there are periods of general quiescence, it follows that there are periods of simultaneous platform-making just below and just above the sea level on all continents. And this is accompanied by an inevitable tendency of the sea to advance upon the land. Now this submerged sea shelf is the special zone of sedimentation, and hence it is the peculiar locus of registration of geologic events. It is at the same time the peculiar habitat of shallow-water marine life, and this is the life which specially enters into the geologic record. We know almost nothing of the ancient abysmal life and relatively little of the land life. Both the physical and the biological record, which are our chief dependence in reading the

earth's history, are therefore made upon the surface of the peripheral terrace and of its inland extension, and hence this becomes preëminently a critical geologic zone.

To follow out the sequence of a typical cycle, let it be supposed that a circumcontinental submarine platform of ample dimensions has been developed, and that it is peopled by a fauna comparable to its extent and resources. It has been suggested that a typical crust movement has for its major feature the depression of the sea bottom and an increase in the capacity of the basin. Let such a movement succeed. The effect of this, whether it involves one ocean basin or all, must be the withdrawal into itself of water from the submerged platforms of all the continents alike, since the oceans are connected. If the basin movement has sufficient magnitude to draw down the sea surface to the terrace edge, the shallow water zone becomes narrowed to a mere strip on the rapidly shelving abysmal face of the terrace, as illustrated in Fig. 3.

FIG. 3.—*a* Former sea level. *b* Succeeding sea level. *c* Former ample shallow-water tract. *d* Succeeding constricted shallow-water tract.

The ample fauna of the previous broader tract is thus forced into the constricted zone and brought under the direst stress of competition and scant room. The destruction of the larger part is inevitable, and the residue is forced to undergo repressive evolution to meet the severe conditions of the new environment. As this is common to all continents, it constitutes a comprehensive evolution of the severely competitive phase. There would, to be sure, be such exceptions as the local variations from the typical configuration of the continental border afford. These might be very considerable. Portions of the continents may have been previously carried down to moderate depths in the sinking of the ocean basins and may become shallow water ground by

the lowering of the sea level. But even then there would remain a community of dominant action that would give a decisive aspect to the progress of life and to the sedimentation on all continents alike.

If now a long period of quiescence follows, a new universal terrace will begin to form and will extend its marine plain seaward and its baselevel inland until at length an ample zone for the evolution of a new shallow water fauna is provided. If to the cutting of the sea edge and the filling in of the sea basin there be added the settling of the continent, the sea may make a wide incursion upon the low parts of the land, as it did in Cretaceous times, and unusual facilities be thus afforded for that form of life-evolution which follows rich and genial conditions.

Thus on the one hand the sinking sea bottom induces that form of evolution in which stress is the dominant factor, and on the other, quiescence induces that form of evolution in which new ground and rich opportunities constitute the dominant condition. Both of these follow simply and inevitably from the sinking of parts that have been already predominant in sinking, and from prolonged intervening stages of quiescence. Almost the only essential postulate of the one evolution is a periodic increase of sea basin capacity; of the other, periodic quiescence. No profound catastrophe is involved; rather on the contrary it is inhibited by the conditions postulated.

Both the evolution of restrictive environment and the evolution of expansive environment, in the opinion of the writer, are effective in the change of faunas, though their respective results may be as different as their modes. In the rhythmical action postulated there is an alternating application of these opposed evolutionary processes with the natural result of an effect of the maximum order; for the evolutionary effects of restrictive conditions are believed to reach their greatest magnitude when they follow conditions of expansion, and, reciprocally, expansive conditions realize their greatest results when they follow conditions of restriction.

Such a succession of shallow sea incursions and withdrawals

reciprocating with crustal movements and quiescence seem to me to be well indicated as the master features of geologic progress from the beginning of the Palæozoic era to the present time. To these features I look for the primary terms of a natural and permanent system of classification and nomenclature.

III. The third agency which affords some promise of becoming a means for strict correlation of transoceanic events and for the division of these events into their natural epochs is an assumed fluctuation in the constitution of the atmosphere. Too little has yet been learned by direct induction respecting the nature of the successive atmospheres of the geologic periods to render this a firm ground for conclusions, but I venture to invite attention to the doctrine enunciated some time ago [1] that the exposure of the crystalline areas to the action of the air necessarily led to changes in the constitution of the atmosphere, especially in the critical element of carbon dioxide. The principle was urged that the greater the exposure of the decomposable crystalline rocks in area and in elevation, by leading to wider contact and deeper penetration of the atmosphere and atmospheric waters, the more rapid must have been the decomposition of the crystalline rocks and the consequent consumption of carbonic acid in the carbonation of the alkalis and alkaline earths, which is the most important part of the decomposing process. This greater exposure obviously followed the crustal readjustments, for at these times the land was largest and highest. It then not only exposed the greatest surface to atmospheric contact, but the atmospheric waters penetrated deepest because of the hydrostatic pressure arising from great differences of water level. At times of approximate degradation to baselevel and of sea-border encroachment the area of action was reduced and the power of penetration of the atmospheric waters became slight because of the low elevation and consequent slight differential pressure. In a word, the consumption of the carbonic acid proceeded rapidly at times of broad and

[1] A Group of Hypotheses Bearing on Climatic Changes. JOUR. GEOL., Vol. V, No. 7, October-November 1897.

high elevation of the land, and slowly at times of low altitude, grand averages being always understood.

If the atmosphere were once excessively burdened with carbonic acid and its later history has been merely a progressive depletion, these stages of rapid consumption only introduced specially rapid reduction of the superabundant supply, and the effects on tangible geological processes may have been quite beyond detection. But if, on the other hand, the atmosphere was limited in amount at the beginning and has been gradually supplied as well as gradually consumed throughout the ages and has been susceptible to serious change, an unusually rapid consumption of the carbon dioxide at the stages of land elevation would result in appreciable depletion of the atmosphere unless the supply were correspondingly increased. On the other hand, at those stages in which the continents were reduced well toward sea level and the land areas were diminished by the incursion of the ocean, the consumption of the carbonic acid would be checked, and if the supply were not correspondingly reduced, reënrichment in carbonic acid would follow. Under this hypothesis, the history of the atmosphere involved alternate enrichment and depletion.

The carbon dioxide is critical because of that peculiar thermal capacity by virtue of which it retains the heat of the sun to a relatively extraordinary degree, a capacity which is shared by water vapor, but which is possessed in very low degree by oxygen and nitrogen. The amount of aqueous vapor, however, is dependent upon temperature, while the carbon dioxide is stable and active at all terrestrial temperatures. Whenever, therefore, there is a notable percentage of carbon dioxide in the atmosphere, it performs a most important function in conserving the heat of the sun and raising the temperature of the lower atmosphere and of the earth's surface. By this rise it increases the aqueous vapor in the atmosphere, which in turn aids the carbon dioxide in retaining the heat of the sun, the two acting conjointly. On the other hand, when the carbon dioxide is reduced to a small factor, the heat of the sun is less effectually

retained at the surface of the earth, the water vapor enters less into the atmosphere and low temperature and aridity are the consequences.

If these considerations are valid, the history of the earth has been marked by periods of relative cold and aridity resulting from stages of rapid rock disintegration, alternating with periods of warmth and moisture correlated with periods of limited rock disintegration and of carbonic acid accumulation. These stages are genetically connected with periods of continental elevation and rapid subaërial degradation, on the one hand, and with slight degradation and sea incursion, on the other. It will be observed that continental elevation as a purely topographical condition contributes to cold and aridity, while continental degradation correlated with oceanic extension contributes to equalization of temperature and to warmth. We have, therefore, the conjoint action of topographic agencies with atmospheric constitution in producing alternations of cold and aridity with warmth and moisture. The aridity is thought to express itself in salt and gypsum deposits and in the red sediments with which these are habitually associated; the cold, in glaciation; the warmth and moisture, in the polar extension of tropical life.

Now these atmospheric influences are strictly simultaneous for all parts of the globe, latitudinal effects, of course, being neglected, for the diffusion of the atmosphere is such as to render its constitution practically uniform for all parts of the globe. In so far, therefore, as atmospheric conditions of a constitutional nature affect the progress of terrestrial phenomena, they affect them universally, and if these influences are pronounced and can be identified they furnish an additional basis for the strict correlation of transoceanic action and for the division of geological history into its natural epochs.

In summation, therefore, I rest in a somewhat confident hope that under continued study adequate natural bases for the more important divisions of geologic time and for a stable and fitting nomenclature will be found (1) in simultaneous internal readjustments alternating with intervals of relative quiescence, (2)

in the periodic development and emergence of circumcontinental terraces and their critical effects on the evolution of life, and (3) in the successive depletions and enrichments of the atmosphere. For subdivisions of lower order the migration of faunas and the special features of continental development will furnish appropriate bases, and below these again, the local phases of sedimentation and faunal adaptation will afford the provincial terms of a natural classification. If this hope be well grounded, the arbitrary divisions that now vex our system may be largely eliminated.

T. C. CHAMBERLIN.

THE POSTGLACIAL CONNECTICUT AT TURNERS FALLS, MASS.

CONTENTS.

The fossil waterfalls.
The promontory.
Montague Plain — clays, gravels and erosion interval.
Glacial channels.
The preglacial Connecticut.
Its postglacial wanderings.
The ice lobes.
Succession of channels.
Lakes of the Lily Pond type.

THE familiar slabs of sandstone with fossil footprints from Turners Falls come chiefly from the "Bird Track Quarry," about a mile from that village on the opposite side of the Connecticut River.[1]

The quarry is on the west shore of a little sheet of water known as the Lily Pond, which is steeply walled with rocks on three sides, opening on the north to a tract of marsh and a stagnant arm of the river called the Cove. These details are clearly shown in Fig. 2, giving on a large scale the actual topography of the region about *A* and *B* in Fig. 1. Fig. 2 is *not* taken from the state map.

The Lily Pond is the pool of an abandoned waterfall made by the Connecticut some time since the last glacial epoch, and occupied long enough for it to cut back an eighth of a mile in the Triassic sandstone. When this path was abandoned the river was fifty feet above its present bed. Fig. 3 shows one wall of the little gorge at the point where the quarry is situated, looking across the pond from the opposite side. The quarry is just beneath the pine tree in the center, the rejected slabs forming the talus heap below.

[1] *A*, Fig. 1.

The rocks about the pool are waterworn in precisely the same way as the similar sandstones beneath the present falls at the village. The edges of the shaly laminæ are frayed and rounded

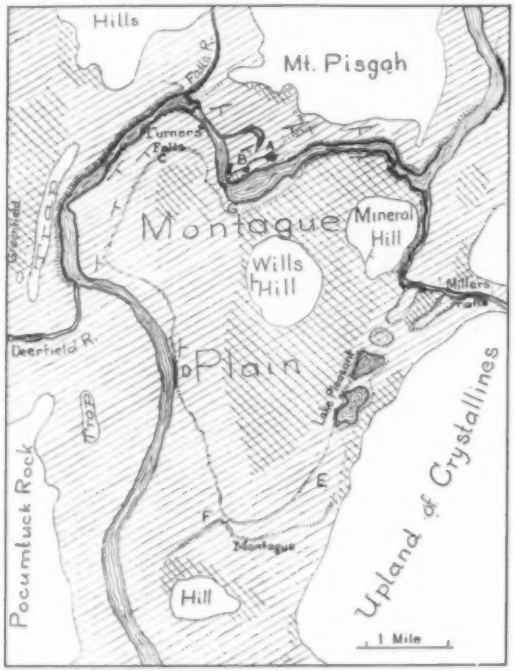


FIG. 1.

as appears in Fig. 4, which is a view of *P* looking from *O* in Fig. 2. Similar effects are observed on all the rocks about.

Besides this fraying of edges, a clear indication of water action, is the complete absence of glaciation about the pool, though elsewhere these sandstones and shales show unmistakable smoothing and grooving on every ledge. Here, despite the rounding in detail, the mass contours of the rocks are sharp and jagged. They have been deglaciated in the rush of waters.

Half a mile further southwest along the same ridge of red shales is Poag's Hole, a similar gorge, somewhat deeper, but of comparable area. Fig. 5 shows the western rock wall. The

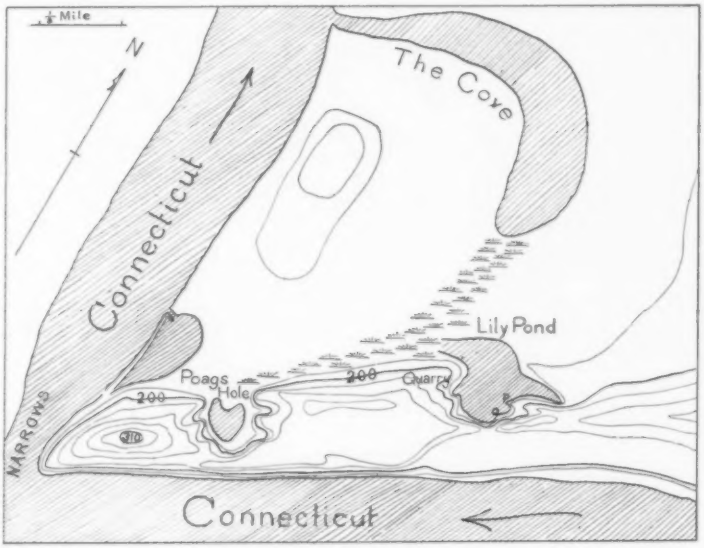


FIG. 2.

crest of the wall at the back is about twenty feet above the crest at the Lily Pond and the sills in front of the pools have nearly the same difference of level. This fall, then, was cut by the river earlier than that at the Lily Pond.

The ridge in which these two gorges are cut has a northern front of exposed shales and sandstones, which strike a little north of east and dip moderately to south. The strata are continuous across the gorges and were once everywhere overlain by clays under sands and gravels, all of glacial origin. The clays are now exposed in the 270-foot flat on the south side of the ridge, between Poag's Hole and Lily Pond. The highest point on the

promontory, west of Poag's Hole, is a cap of gravelly sands that bring it up to the level of Montague Plain, of which it was doubtless once a part, most of the sand and clay having been

FIG. 3.

removed by the river as it cut its way down toward the rock. Fig. 6 is a section through the highest point of the ridge just west of Poag's Hole.

Montague Plain is roughly outlined in Fig 1, the single-lined area suggesting the original extent of the plain formation, and the cross lined part being still at about the original level. The upper portion of the plain is everywhere of sand and gravel somewhat irregularly stratified.

The formation has a considerable extension in Greenfield Meadows and lesser ones to north and south. The gentle undulations of the surface, together with the lack of sharp stratification suggests that the sands were not laid down in standing water, but rather strewn here and there by the detritus-laden

floods from the melting ice on the hills, checked here in their steep descent, and arriving largely through the valleys of the Millers and Falls rivers.

FIG. 4.

Under the sands are clays observed at various levels from 190 to 270 feet above the sea. They rest on the glaciated sandstone, are beautifully stratified, occurring mostly in half-inch layers, greenish and butter-like, with gritty sandy layers from two to four inches thick between. They are exploited for brickmaking at several points in the escarpment around Montague Plain.

In the clay pits beside the track at Greenfield the stratification is clear and horizontal as elsewhere, but the upper surface of the clays, as revealed by the workmen, is uneven and not parallel to the stratification, while the transition from clay to

gravel is abrupt. At Keith's Spring (Fig. 1, *G*), 200 feet above sea, is a little hill of the laminated clays at the foot of the bluff, with its strata running squarely into the sand of the bluff across the intervening air. No other agency than the different rates of atmospheric wear on clay and sand is apparent to account for the notch between the clay hillock and the bluff. A similar hillock of laminated clays occurs half a mile further north. These three occurrences and the varying upper limit of the clays observed point to erosion of the clays before the sands were laid down. Yet in several of the sections the true surface may be masked by sand that has fallen down from above.

The present course of the Connecticut around the plain is of course postglacial and much of it is gorge cut in the rocks. Such rock-cutting is indicated on the map by heavy lines on the river margin. Though superposed on the rock structure underlying the plain this part of the river has now a certain adjustment to the structure as may be seen by the stratigraphic marks on Fig. 1 which indicate well-established facts.

Preglacially the channel was probably straight down from the northeast corner of the map by Millers Falls, and Lake Pleasant and thence westward to the present channel somewhere between *D* and *F*, points where ledges are now exposed.

Between the occupation of the ancient and modern channels there are indications of some persistence of the drainage across the plain by a west channel and an east channel. Indications of water passing through the west channel are:

(1) the gentle depression between *G* and *D* (Fig. 1), and (2) the frayed and waterworn state of a rock ledge at the 220-foot level (*D*), a hundred feet above the present river.

The east channel is better marked, being indicated today by deep sags in the plain at Millers Falls; kettles to the south, two of them occupied by the Lake Pleasant ponds; and the long deep valley to the south by which the lake drainage escapes to the river. The higher ground between the kettles is yet below the surface of the plain. This is shown in Fig. 7, taken

on the higher land between Lake Pleasant and the next kettle to north. The gentle hollow in the foreground represents the ground between the kettles. The tree tops in the middle dis-

FIG. 5.

tance indicate the location of the kettle.[1] Fig. 7 was taken to show that even if the kettles were filled up, there would still remain a shallow valley in the plain. The deeper southern por-

[1] This kettle, like the 100-foot cliff at *D* and some other features, does not appear on the Greenfield topographic sheet. The Lily Pond ridge also is quite misrepresented.

tion of the valley (at *E*) is in the clay, and brickyards are located there.

If the broad valley southwest from Turners Falls between the Greenfield trap ridge and the northwest bluff of Montague Plain was cut out by the modern river, it is remarkable that the cutting should have ceased a few feet above the rocks. But as

Fig. 6

these are beautifully glaciated and buried under a thin cover of drift, it is hard to believe the water has actually flowed over them. Moreover a curious remnant of sandplain (?) standing on the northwest corner of Montague Plain (at *C*) seems to indicate that ice filled this valley all through the building of the plain. The wearing back of the bluff has cut away most of this sandplain, but a section near Mr. Burnet's discloses the foreset beds and some of the topset. Sands on that side would have come from the hills to the northwest by the valley of the Falls River.

Kettles like those of the east valley we are wont to associate with drift-buried ice blocks. From the alignment with the old upper valley of the Connecticut, as seen in the northeast corner of the map, this chain of depressions might represent the burial in outwash sands of the decayed remnants of a valley ice tongue, the sands being supplied from the earlier revealed hills to north and east. The ice-tongue here however must have rested above the clays, unlike the tongue to the northwest. If this inference is correct, as the clay floor at *E* seems to make it, we must suppose the clays were laid down during a withdrawal of the ice-front from this area while it was either laked or depressed beneath the sea, and that subsequently the ice advanced again to southward, reaching its valley-tongue out over the clays where in the final melting of the ice it rolled

into a number of great fragments and was buried in the sands.

Chief attention is here called to the topographic facts which it is believed are accurately described. The succession of events

FIG. 7.

which seems most plausible is here offered as an hypothesis for present use. This hypothetical history is as follows:

1. Ice advance.
2. Ice retreat, leaving Turners Falls ice-tongue.
3. Deposition of clays.
4. Ice advance, east valley tongue overriding clays.
5. Ice retreat, leaving east valley ice tongue.
6. Building of Montague Plain and burying east valley ice.
7. Clearer waters pass through west valley.
8. Turners Falls valley ice melts, tempting Connecticut across the ridge where it cut successively Poag's Hole, Lily Pond and the Narrows.

9. East valley ice melts leaving modern topography.

10. The trenching river finds the rocks and cuts its gorge with present falls and rapids.

Ponds, such as those here described should be fairly numerous in glaciated regions. The kettle ponds are of course widely observed.

Pools of abandoned falls of glacial origin are not often cited. A superb example is noted by I. C. Russell[1] at the foot of a 400-foot basaltic cliff near Coulée City, Washington, over which the waters of the Columbia plunged when an ice dam drove them through the fault chasm of the Grand Coulée (p. 91). Another such pool is Thaxter Lake near Taylor's Falls, Minnesota, excavated by the tumbling waters of the deviated St. Croix.[2] Other fine examples are the Green Lakes at Jamesville and other points near Syracuse, reported by Gilbert and lately described by Quereau.[3] Here magnificent glacial outlets of Lake Iroquois, paralleling the Mohawk outlet, but farther south, cut broad trenches across the promontories of the ragged escarpment south of Syracuse and plunged Niagara-like into great basins below. The trenches are now dry high in the hills, but the basins are filled with placid greenish waters.

M. S. W. JEFFERSON.

[1] Bull. 108, U. S. Geol. Surv.

[2] Berkey, Am. Geol. Dec. 1897, p. 352.

[3] Bull. Geol. Soc. Am., Feb. 1898.

THE VARIATIONS OF GLACIERS. III.[1]

THE following is a summary of the Second Annual Report of the International Committee on Glaciers:[2]

RECORD OF GLACIERS FOR 1896.

Eastern Alps.—Nearly all the glaciers are receding, though a few have begun to advance. The Bavarian glaciers show a marked recession.

Swiss Alps.—The advance shown by many glaciers between 1880 and 1893 is fast disappearing. The Rosegg glacier (Engadine) is advancing, as were recently some glaciers on the not distant Ortler.

Italian Alps.—A considerable interest is being awakened in Italy in the variations of glaciers. The Italian Alpine Club, the Alpine Society of Frioul, and the Italian Geographic Society are all encouraging the study of glaciers. Those under observation in the central chain show a marked retreat. Eight glaciers have been examined in the Maritime Alps, and all seem to be diminishing.

Scandinavian Alps.—Much activity is being shown in Sweden in the study of the recently discovered glaciers, but it is still too soon for extensive results. One glacier, the Soltja, has advanced very slightly; the others seem to be stationary. Some interesting temperature observations were made. Minimum

[1] The first two articles of this series appeared in this JOURNAL, Vol. III, pp. 278–288; Vol. V, pp. 378–383.

[2] Archives des sciences phys. et nat., Vol. IV; Geneva, 1897. Some changes have occurred in the membership of the committee. Mr. D. W. Freshfield has replaced Captain Marshall Hall, deceased, as representative for Great Britain and her colonies; Professor G. Marinelli has replaced Professor T. Taramelli, resigned, as representative for Italy; Professor A. G. Nathorst has been appointed to represent Spitzbergen and other Arctic regions not belonging to any civilized nation. We have also to record the sad death of Professor Léon du Pasquier, at the beginning of a career full of promise.

thermometers, placed on the summits of certain mountains, recorded —17° C., against —40° in the neighboring valleys.

Greenland.— Mr. Steenstrup has attempted to determine whether the inland ice has suffered periodic variations, but has been unable to arrive at definite conclusions.

We have a description of the inland ice, written in the year 1200, which would apply to its present condition. A dozen glaciers in the Umanak fiord are the only ones that have been sufficiently studied to yield results of value. Some show no sensible variations; others show variations of rather short periods, dependent probably on the rate of flow. Generally it can be said that there has been no marked change in the length of the glaciers during this century, but the tendency seems to be for an advance rather than for a retreat. A table of twenty-six measures of the velocity of various Greenland glaciers shows motions ranging between one-quarter inch and 124 feet a day.

Professor Mouchketow, representative for Russia, makes the following report:[1]

Caucasus.— Measurements of nine glaciers in different parts of this chain show a retreat varying from 30 to 125 feet yearly for the last eight or ten years; though in the central Caucasus some of the névé fields are growing thicker. About forty glaciers were visited in 1896 in the mountains of Teberda and Maroukha, several of which were unknown before. They are receding, and we may say that the glaciers of the Caucasus are generally in the state of retreat.

Turkestan.— Many glaciers have been discovered in the Ghissar Mountains and the neighboring chains. They are small and do not descend below 11,000 feet. They occur in groups; the majority lie on the northern slopes, and are for the most part entirely covered with snow; this was more general than usual in 1896, on account of the heavy precipitation, which also characterized that year in the Alps. The positions of the moraines show a general retreat of these glaciers.

[1] Professor Mouchketow gives the names and locations of a large number of glaciers.

Siberia.—The principal observations are in the region of Beloukha; the glaciers show a very marked decrease in size.

RÉSUMÉ.

Although it is too early to attempt to form definite conclusions, still the reports seem to indicate pretty generally that the glaciers of the world are getting smaller. The few local cases of advances are of small importance. No region observed shows a general advance of its glaciers such as took place in the Alps in 1816–1820.

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1897.[1]

But little information has been obtained regarding the variations of glaciers in the United States between 1896 and 1897.

Chaney Glacier, a small, steep glacier in the Rocky Mountains of Montana, discovered in 1895, is retreating. (L. W. Chaney.)

Carbon Glacier, on Mount Rainier, has retreated about seventy-five feet between 1896 and 1897. (Plummer.)

Mr. I. C. Russell reports a glacier on Mount Stuart, and Mr. M. W. Gorman reports glaciers on Bonanza and on North Star Mountain, all in the State of Washington.

The glaciers of the Kenai peninsula, Cook's Inlet, Alaska, have been mentioned, but not described, by earlier writers. Mr. F. H. Curtiss has sent me a short description, from which the following is condensed:

The ridge running along the southeastern side of Kachemak Bay is over 3000 feet high; the upper part is covered with snow, from which glaciers descend through deep gorges nearly to the sea level.

The tongues of the glaciers are about five miles long and from three-quarters to one and a quarter miles wide; they all have terminal moraines. A few have been named. The

[1] A synopsis of this report will appear in the Third Annual Report of the International Committee. The report on the glaciers of the United States for 1896 was given in this JOURNAL, Vol. V, pp. 381-383.

Grewingk has apparently retreated about 600 feet in fifteen years. The next glacier to the northeast, though fed by the same fields, seems to have receded very little.[1]

Mt. Iztaccihuatl, in Mexico, has a snow cap from which a small glacier, the Porfirio Diaz or Ameca, protrudes (a second glacier has retreated to the snow-line). Señor Ezequiel Ordoñez, of the Mexican Geological Survey, has put out signals to study its variations. Excellent descriptions and reproductions of photographs of this glacier have been given by Dr. Oliver C. Farrington, of Chicago, with references to the literature.[2]

HARRY FIELDING REID.

GEOLOGICAL LABORATORY,
JOHNS HOPKINS UNIVERSITY,
June 28, 1898.

[1] A map showing a part of this region, with corrections by MR. CURTISS, has been published by Professor William H. Dall. Coal and Lignite of Alaska, U. S. Geol. Surv. 17th Ann. Rept., 1896, p. 786.

[2] Observations on Popocatepetl and Iztaccihuatl, Field Columbian Museum, Publication 18; Chicago, 1897. Dr. Farrington has overlooked the interesting pamphlet of SEÑOR EZEQUIEL ORDOÑEZ, Notas acerca de los ventiqueros del Iztaccihuatl; Memorias de la Sociedad Cientifica "Antonio Alzata;" Mexico, 1894.

NOTES ON THE KALAMAZOO AND OTHER OLD GLACIAL OUTLETS IN SOUTHERN MICHIGAN.

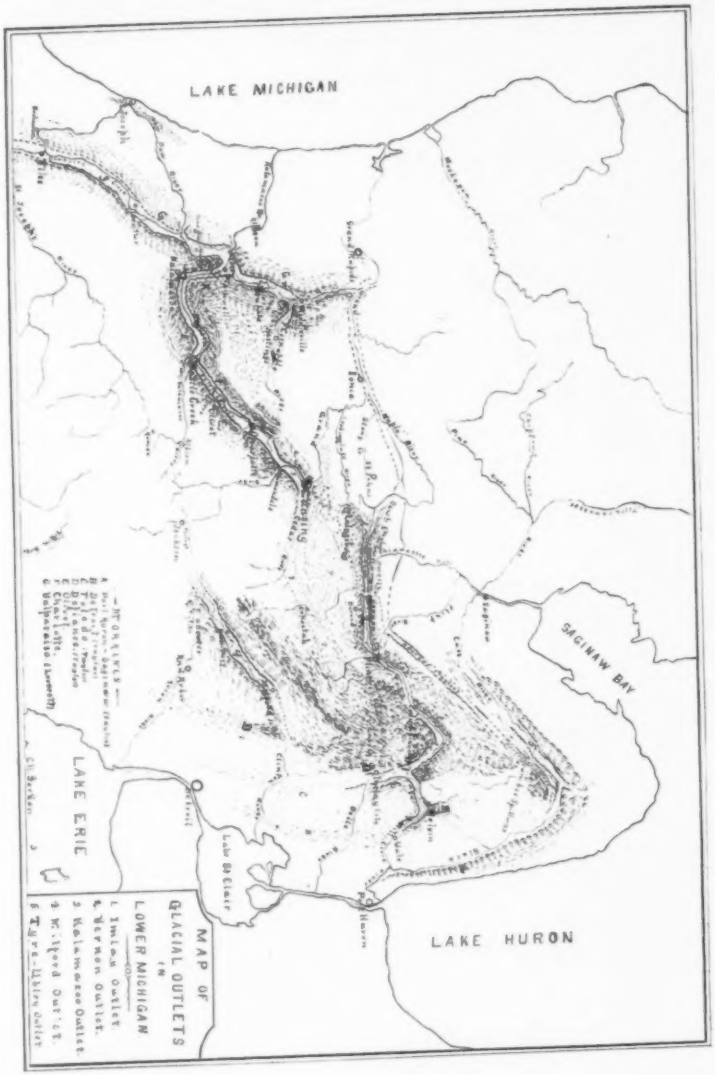
HAVING occasion recently to cross the state from Melvin near Port Huron to Plainwell, the writer took advantage of the opportunity to make the trip by wheel for the purpose of studying some of the problems of glacial drainage suggested by previous studies. It had been observed earlier that between Plainwell and Battle Creek the Kalamazoo River occupies a wide valley evidently of prior origin. Above Battle Creek the valley is much narrower, while a broader channel bears off to the northeast and furnishes an outlet for the Battle Creek. In eastern Michigan the observations of Taylor, Gilbert, and others have disclosed the existence of several old outlets, though the courses of some of them have not been completely traced. One of these, the Imlay, was traced by the above authors northward past Imlay to North Branch, thence southwestward to Columbiaville. Further, in a letter to the writer, Dr. A. C. Lane, Assistant State Geologist, has pointed out the existence of an old channel between Milford and Hamburg Junction, which is now occupied by the Huron River. Did the Imlay outlet discharge by way of the Kalamazoo or was the latter the outlet for the waters of the Milford channel? While the time at the writer's disposal did not permit a full investigation, the facts obtained are deemed of sufficient interest to warrant their publication as a contribution toward the elucidation of the glacial history of the state.

The Imlay outlet.—This outlet, described and mapped by Taylor,[1] was crossed by the writer near its summit level about ten miles southwest of Brown City. South of this point the swamp which marks the position of the channel is drained toward the northeast by Mill Creek. As far as Yale this creek

[1] Bull. Geol. Soc. of Amer., Vol. VIII, 1897, pp. 31–58.

flows in an old channel which probably received the glacial waters when the ice front had retreated to the position of the Detroit moraine at Melvin and poured them westward into the Imlay outlet. Near Columbiaville there are indications that the waters escaped southward toward Lapeer, following the line of the headwaters of the Flint River, while another smaller trough appears to lead southwest, crossing the line of the C. & G. T. Railway just west of Elba. The latter is well situated to constitute the continuation of the Imlay channel, but the elevation of the bottom of the valley, which is about 800 feet, or thirty feet above that of the Imlay at Columbiaville according to Taylor, would seem to militate against that conclusion. The relations here are somewhat obscure and more detailed investigations are needed to settle the question.

The Vernon outlet.—Below Columbiaville the Flint River crosses a moraine which is seemingly the Saginaw, equivalent of the Toledo moraine. At Flint also the river with an abrupt turn breaks through a northward lying parallel ridge which we take to be the equivalent of the Detroit moraine. The valley of the stream where it crosses the first mentioned moraine is much wider than where it crosses the second and has evidently been occupied for a longer time. Before passing through the break in the second moraine it receives a branch from the southwest called Swartz Creek. This stream flows in an old channel which was followed by the writer many miles westward along the south border of the moraine which we may here call the Vernon moraine, from the village of that name which is situated upon its slopes. West of Otterburn the Chicago and Grand Trunk Railway follows the valley bottom as far as Duffield, the stations here being nearly on a level with the valley floor. At Duffield the channel bears directly westward past Vernon. It was followed to a point about nine miles west of this place, or twenty-seven miles in all. The channel has a width of three-fourths of a mile and is covered in part by a black, mucky soil. In places where the drainage is not well established it is wet and swampy. At one point dredging revealed the presence of


LAKE MICHIGAN
SAGINAW BAY
LAKE ERIE
LAKE HURON
MAP OF
GLACIAL OUTLETS
IN
LOWER MICHIGAN

gravel beneath the muck. Outside the muck area which comprises a belt of varying width extending along the middle of the valley the floor is covered with sandy gravel. Bowlders are not abundant though one field was seen to be thickly strewn with them. Toward the east this portion of the channel is drained by Swartz Creek, which enters it from the south about a mile west of Swartz Creek station, and toward the west it is drained by a branch of Maple River. The middle portion is intersected by the Shiawassee River and one of its branches. The Shiawassee enters the valley about three miles west of Vernon and follows it to the latter place, where it breaks through the moraine northward. The further course of the channel westward is not known, but it probably either continues past St. Johns down Stony Creek or follows the Maple by way of Duplain to the old Grand River outlet. If the Vernon moraine is the equivalent of the Detroit moraine as we infer, then the Vernon outlet must have been active at the time the Mill Creek channel was open at Melvin, the waters from which found their way westward through the bend of the Imlay outlet, though at a later stage the latter may have been abandoned for an outlet farther north, possibly by way of Otter Lake. Within the limits described the known elevations of the channel floor as shown by the railroad levels at the stations named, which are generally within a few feet of the bottom level, are as follows: Otterburn 771, Swartz Creek 779, Crapo 774, Duffield 780, Vernon 780.

The Kalamazoo outlet.—This is one of the most important of the glacial outlets observed within the state. Previous observations had shown the existence of a channel between Battle Creek and Plainwell, but its extension east and west from these points was unknown. Our recent observations have shown that this channel extends northeastward from Battle Creek as far as Lansing, at which point it turns eastward, but beyond which it has not been traced. From this place to Plainwell it follows the outer border of a moraine (*F*), here named the Charlotte moraine from the city of that name which is situated upon it

Between Plainwell and Otsego it turns abruptly southward along the outer border of the Valparaiso moraine (*G*), past Decatur and Niles to South Bend, and thence evidently, according to Leverett's observations, the waters reached the Illinois River by way of the Kankakee. On the south and east side the waters were confined by the Olivet moraine (*E*). Between Lansing and Plainwell the channel has an average width of about a mile, but is somewhat wider in its lower portion. At the bend near Kalamazoo it has a width of two and a half miles and at Plainwell it is much wider. At Plainwell a branch comes in from the northeast by way of Gun Lake that is in direct connection with the upper part of the valley of the Thornapple River which is here wide and was evidently active as an outlet at a later stage than the Kalamazoo. The connection between the Thornapple and Gun Lake divisions is through a series of small lakes and marshes in Yankee Springs township.

Between Dimondale and Charlotte the Kalamazoo channel is marked by a long narrow marsh some portions of which have been brought under cultivation. Similar marshy tracts occur also between Charlotte and Battle Creek, at Kalamazoo and south of Otsego. At Kalamazoo the mucky soil has been utilized for growing the celery for which that city has become noted. Outside the mucky areas the channel floor is covered with sand and gravel. In some places sand predominates and often occurs in low mounds and ridges. Gravel, however, mixed with more or less sand is the principal constituent of the valley filling. Gravel beds occur along the sides of the valley as remnants of a terrace, the top of which is about fifteen feet above the general plain level. Cultivated fields generally show an abundance of cobble stones strewn over the surface and in some places bowlder patches occur. At Charlotte gravels constitute the low divide between the headwaters of Battle Creek and Thornapple River occupied by the Grand Rapids branch of the Michigan Central Railway. At Plainwell a bluff of gravel twenty feet high extends along the north bank of the river which here flows over a stony bottom.

At Dimondale the Grand River enters the valley from the southeast and follows it to Lansing, a distance of nine miles, where, after receiving Cedar River, it passes through the Charlotte moraine northwestward. The marshy tract between Dimondale and Charlotte is drained westward through the Thornapple, while below Charlotte the drainage is effected by Battle Creek. At Otsego the Kalamazoo leaves the old channel and passes out westward through a narrow gorge in the Valparaiso moraine.

The elevations of railroad stations which appear to be situated about on the level of the valley floor are as follows: Lansing (C. & G. T. R. R.) 836, Battle Creek (C. & G. T. R. R.) 823, (M. C. R. R.) 818, Bedford (M. C. R. R.) 807, Augusta (M. C. R. R.) 789, Galesburg (M. C. R. R.) 788, Comstock (M. C. R. R.) 778, Kalamazoo (M. C. R. R.) 770, (G. R. & I. R. R.) 778, Cooper (G. R. & I. R. R.) 774, Travis (G. R. & I. R. R.) 746, Plainwell (G. R. & I. R. R.) 741, Alamo (M. C. R. R.) 764, Williams (M. C. R. R.) 759. If the Kalamazoo channel received the waters of the Imlay outlet during the earlier stage of the activity of the latter, as we are inclined to believe, further investigations will probably show a connection to exist by way of Cohoctah and Lapeer or west of the latter place. However, more detailed work will doubtless bring to light other lines of drainage and until such work is done no reliable prediction can be made. During the time of greatest activity of the Kalamazoo outlet when the edge of the Saginaw lobe occupied the position of the Charlotte moraine and that of the Michigan lobe was at the position of the Valparaiso moraine, the waters from the two opposing ice fronts north of Plainwell evidently came down by way of the Gun Lake branch. Later when the Saginaw lobe had retreated to the north side of the Thornapple River, the principal drainage must have been by way of the Thornapple and Gun Lake channel.

The Milford channel.—The only part of this channel as yet known is the wide valley occupied by the Huron River between Milford and Hamburg Junction. It has been suspected that this channel connected with the Kalamazoo outlet, but from what has

preceded it is evident that the westward extension of the Milford channel must be sought farther south. From the behavior of the rivers and the general character of the drainage it is suspected that the course of this channel lies westward along Portage Creek, a few miles north of Jackson, then southwestward by way of Homer, and thence down the St. Joseph River, joining the Kalamazoo at South Bend.

Reversal of Drainage.—The limited amount of study thus far given to the region has shown the existence of many interesting examples of stream piracy and reversed drainage. The writer has pointed out one of these in the case of Black River near Port Huron.[1] Several others can be readily pointed out on the accompanying map. It is evident that the region of southern Michigan offers excellent opportunity for physiographic study, and the legislature of the state could not perform a better service than to make a liberal appropriation to the geological survey for the purpose of putting this material in shape for the use of the public schools.

C. H. GORDON.

[1] JOUR. GEOL., Vol. V, 1897, p. 315.

NOTES ON SOME IGNEOUS, METAMORPHIC, AND SEDIMENTARY ROCKS OF THE COAST RANGES OF CALIFORNIA.[1]

The metabasalts and diabases of the Coast Ranges.—There are very abundant masses of greenish rocks in the Coast Ranges which are often massive, but sometimes form distinct breccias. The microscopic investigation of these rocks show them to be of igneous origin, and to largely represent old lavas. Many such rocks were supposed by Professor Whitney, the former state geologist of California, to be metamorphic sandstones. Dr. Becker, in his investigation of the quicksilver deposits[2] of the Pacific slope, regarded some of them as metamorphic sandstones, and gave such the name "pseudo-diabase" and "pseudo-diorite." In an investigation of the geology and petrography of Mt. Diablo,[3] I found that some of the so-called metamorphic sandstone of Whitney was true diabase and unquestionably of igneous origin. In this conclusion, Dr. Becker concurred. More recently Dr. Ransome,[4] in a study of the rocks at Pt. Bonita, California, found there similar rocks, which he called basalt and diabase. Still later, Ransome, in an investigation of the geology of Angel Island, found certain greenstones which he considered as allied to fourchite, although admitting that feldspar might have been present in the rock, as indicated by the great abundance of a zoisite-like mineral in some thin sections.

In 1897, in company with Mr. J. S. Diller, I visited Angel Island and collected there specimens of the so-called fourchite, and of other rocks. Some of these specimens show plenty of fresh plagioclase and there is therefore no doubt that some of

[1] The author, doubtless due to absence in the field, has been unable to read the proof of this article.

[2] Mon. XIII, U. S. Geol. Surv. [3] Bull. Geol. Soc. Am., Vol, II, pp. 383-414.

[4] Bull. Dept. Geol., University of California, Vol. I, pp. 71-114.

this greenstone is a feldspathic rock, and not a fourchite. However, if we suppose that the pyroxene in the specimen analyzed by Ransome be an ordinary aluminous augite, and that all the magnesia of the rock is in the augite, a calculation shows that the rock contained about 80 per cent. of augite, so that in this specimen the feldspar must have existed in small amount. The specimens from the Angel Island fourchite area which I examined have the structure and composition of a holocrystalline basalt in which the augite shows an idiomorphic tendency, as it often does in modern doleritic basalts. The Angel Island greenstone may, therefore, be called in part a metabasalt, and this term should likewise be extended to the basaltic rocks at Pt. Bonita, inasmuch as in all cases the basalts have undergone extensive metamorphism. A comparison of the analyses of the spheroidal basalt at Pt. Bonita, with that of the fourchite at Angel Island, and of other greenstones from other portions of the Coast Ranges,[1] brings out very clearly the similarity in composition of these greenstones at widely separated localities.

ANALYSES OF METABASALTS AND DIABASES FROM THE COAST RANGES.

	I Fourchite from Fourche Mt.	II Fourchite from Angel Island	III Diabase, Pt. Bonita	IV Diabase, Pt. Bonita	V Spheroidal basalt, Pt. Bonita
Silica	42.03	46.98	45.59	46.28	49.45
Alumina	13.60	17.07	20.99	12.96	17.58
Ferric oxide	7.55	1.85	2.49	4.67	3.41
Ferrous oxide	6.65	7.02	4.36	6.06	3.41
Lime	14.15	12.15	7.57	10.12	7.20
Magnesia	6.41	8.29	8.95	8.71	4.05
Potassa	.97	.53	} 4.89	3.75	1.57
Soda	1.83	2.54	}		5.83
Analyst	Brackett and Noyes	Ransome	Ransome	Ransome	Ransome

1. Fourchite from Fourche Mountain, Arkansas. (Ann. Rept. Geol. Surv., Arkansas, 1898, Vol. II, on "The Igneous Rocks of Arkansas," by J. Francis Williams, p. 108.) This

[1] See table of analyses.

rock is composed of 75 per cent. of augite and secondary material, probably leucoxene, with a highly altered ground mass.

2. Fourchite from Angel Island. (Bulletin Dept. of Geol. University of California, Vol. I, p. 231.) Ransome.

3 and 4. Diabase from Pt. Bonita. (4th Bulletin Dept. of Geol. University of California, Vol. I, p. 106.) Ransome.

5. Spheroidal basalt from Pt. Bonita. (4th Bulletin Dept. of Geol. University of California, Vol. I, p. 106.) Ransome.

	VI Epidiorite-Potrero	VII Pseudo-diabase Mt. St. Helena	VIII Pseudo, diabase, Sulphur Bank	IX Diabase, Mt. Diablo	X Diabase, Mt. Diablo
Silica	47.41	49.08	51.28	51.58	52.06
Alumina	16.03	14.68	15.05	14.99	14.34
Ferric oxide	2.66	1.95	2.41	2.04	2.11
Ferrous oxide	7.05	9.63	8.01	8.36	7.74
Lime	12.33	10.09	7.08	8.59	8.05
Magnesia	5.81	6.69	6.07	6.51	9.26
Potassa	4.47	0.20	0.12	0.31	0.73
Soda		4.60	4.43	3.08	1.74
Analyst	Palache	Melville	Melville	Melville	Melville

6. Epidiorite Potrero. (Bulletin of Geol. University of California, Vol. I, p. 177.) Palache.

7. Pseudo-diabase from near Mt. St. Helena. (Monograph XIII, U. S. G. S., Becker, Quicksilver Deposits, p. 98.)

8. Pseudo-diabase, Sulphur Bank. (Mon. XIII, p. 99.) Becker.

9 and 10. Diabase from Mt. Diablo. (Bulletin Geol. Soc. Am., Vol. II, p. 412.) Turner.

Serpentine.—There are very abundant areas of serpentine in the Coast Ranges, single masses often covering many square miles. The occurrence of serpentine was noted by the geologists who accompanied the Pacific Railroad exploration parties, and the first analysis of a California serpentine which I have found recorded, is that given by Professor Newberry, and is of a specimen collected at the Presidio at San Francisco. Later,

Professor Whitney, in the study of the Coast Ranges, came to the conclusion that the serpentine originated from the alteration of sediments. Dr. M. E. Wadsworth,[1] who studied the Whitney collection of rocks, however, subsequently described some of the serpentines and pyroxenites and peridotites from serpentine areas in California, as probably being igneous rocks. Professor Whitney, under whose supervision Dr. Wadsworth worked, does not appear to have objected to this.

When Dr. Becker undertook the investigation of the geology of the quicksilver districts, the difficulty of accounting for the great change in chemical composition of any sediment to a rock with the composition of serpentine was very apparent. However, he found evidence of such alteration in the sandstones of what is now known as the Franciscan or Golden Gate series. Some of these sandstones contain igneous material, derived undoubtedly from preëxisting igneous rocks or from volcanoes of the Golden Gate period, and some of this igneous material undoubtedly has formed some serpentine. Indeed, needles of serpentinoid material were noted eating their way into grains of quartz, and such evidence led Dr. Becker to conclude that considerable masses of serpentine were thus formed. He suggested that sufficient magnesia for such a metasomatic change might be derived from the micas of the granites which underlie the Coast Ranges. Dr. Becker[2] later (1893), however, regarded some of the serpentine masses described in the quicksilver monograph as being altered peridotites.

In my field work at Mt. Diablo I came to the conclusion that the serpentine there is of igneous origin, as I found traces of the original pyroxene and olivine of the peridotite from which the serpentine was derived at several points. Dr. Charles Palache, in his bulletin on the rocks of the Potrero, San Francisco, likewise concluded that the Potrero serpentine is of igneous origin, and Dr. Ransome treated the serpentine of Angel Island

[1] Lithological Studies. Memoirs Mus. Comp. Zoöl., Vol. XI, Pt. I, pp. 129, 132, 142 and 158. (See also general discussion of the origin of peridotite, pp. 189–192.)

[2] Mineral Resources of the U. S. for 1892, DAY, p. 144.

ANALYSES OF SERPENTINES FROM THE COAST RANGES.

	No. 223, Mt. Diablo	No. 176, Mt. Diablo	No. 222, Mt. Diablo	Presidio	No. 78 *b*, Sulphur Bank	No. 181, Mt. Diablo	No. 110, New Idria	No. 78 *c*, Sulphur Bank	Angel Island
Si_2O	34.84	36.57	36.96	39.60	39.64	40.50	41.54	41.86	42.06
Cr_2O_3	0.68	0.33	0.78	.20	0.29	0.41	....	0.24	....
Al_2O_3	0.42	0.95	0.39	1.94	1.30	0.78	2.48	0.69	2.72
Fe_2O_3	6.08	7.29	5.00	....	....	4.01	....	....	
FeO	1.85	0.37	2.34	8.45	7.76	2.04	1.37	4.15	2.88
MnO	0.01	0.10	0.09		0.12	0.13	....	0.20	....
NiO	Trace	0.31	Trace	....	0.33	0.11	0.04	Trace	....
CaO	7.02	0.14	3.81	....	....	0.39	....	....	....
MgO	30.74	40.27	33.84	36.90	37.13	37.43	40.42	38.63	39.53
K_2O	0.07	Trace	0.14	....	....	0.16	....	....	....
NaO	0.42	0.31	0.34	....	....	0.28	....	....	....
H_2O above 100° C	15.72	12.43	14.02	12.91	12.91	10.94	14.17	14.16	12.04
Analyst	Melville	Melville	Melville	Easter	Melville	Melville	Melville	Melville	Ransome

Analyses Nos. 223, 222 176, and 181, from Mt. Diablo are taken from Bull. Geol. Society of America, Vol. II, pp. 383-414. The analyses of the Presidio rock is by J. D. Easter, and is from a report by Professor J. S. Newberry, in the Pacific Railroad report, Vol. VI, Part II, p. 11.

Analyses Nos. 78 *b*, 78 *c*, and 110 are taken from Monograph XIII, U. S. Geol. Surv., by G. F. Becker.

The analyses from Angel Island are taken from the Bulletin Department of Geology, University of California, Vol. I. p. 106.

as a metamorphosed igneous rock. The Angel Island rock was, however, considered as possibly being derived chiefly from diallage, but the analysis given shows clearly that no such derivation is possible. The table of analyses given below indicates how uniform in chemical composition the serpentines of the Coast Ranges are, and also that olivine or rhombic pyroxine must have been a prominent constituent of all of the original rocks from which the serpentines analyzed were derived.

The Franciscan or Golden Gate formation.—The metamorphic rocks of the Coast Ranges, and the associated cherts, sandstones, and shales, were formerly considered as of the age of the Knoxville beds; that is, lower Cretaceous. The more highly metamorphosed of these rocks are green amphibolite-schists, blue amphibolite-schists (glaucophane-schists), mica-schists, chlorite-schists, and various other schistose rocks. In my bulletin on Mt. Diablo, it was assumed that the red cherts or jaspers were silicified shales, and that these jaspers, together with the sandstones and schists associated with them, were the result of regional metamorphism of the Knoxville formation. Since that time it has apparently been shown, chiefly by Dr. H. W. Fairbanks, that these jaspers, associated sandstones, and schists are older than the Knoxville beds, and probably of Jurassic age. The best description of this series of rocks is that by Professor A. C. Lawson in his "Sketch of the Geology of the San Francisco Peninsula."[1]

One of the most interesting rocks of the series is the blue amphibole-schist, which is often found in croppings in or near serpentine masses. The blue amphibole is perhaps in part glaucophane, and these rocks have, therefore, generally been called glaucophane-schists. Dr. Ransome, in his study of the geology of Angel Island, found these schists at so many points on the border of serpentine masses that he concluded that they were contact metamorphic rocks. Professor Lawson, in the paper above referred to, considered the schists rich in amphibole to be metamorphosed volcanic material, but ascribed their origin, in

[1] Fifteenth Ann. Rept. U. S. Geol. Surv.

part at least, to contact metamorphism, and not regional metamorphism, believing that Dr. Ransome has established this in his bulletin on Angel Island. Professor Lawson seems to me to state the case very fairly. He writes as follows:

"In some few cases the schist areas have a very definite relation to dikes and laccolitic lenses of serpentine, and some of the most highly altered phases of schist that have been found, both of the micaceous and the blue amphibole varieties, have been taken from the immediate contact with the serpentine. In these cases there seems to be little doubt that we are dealing with a contact zone. In other cases, however, we have the immediate contact of serpentine and sandstone well exposed with no perceptible development of schist at the contact and little alteration of any kind appreciable to the unaided eye beyond a narrow zone of hornfels. It seems clear, therefore, that the metamorphic action of intrusive peridotite upon the rocks which it invades is not uniform, and the conditions which determine in some cases a maximum and in some cases a minimum of metamorphism are not yet known."

The point Lawson makes, that serpentine in many cases has merely hardened the sediments into which it is intruded and has not metamorphosed them, is perhaps of vital importance in discussing the origin of these schists. In the case of granitic intrusions into sediments, as everybody knows, there is always a zone of metamorphism all around the mass, and the conclusion that the granitic rock has caused this metamorphism appears to be absolutely demonstrated. When, therefore, we have an igneous intrusion which is bordered by schists on one side and by little altered sediments on the other, and if we know the latter to be older than the igneous mass and intruded by it, it is difficult to imagine conditions which cause such variable effects if we ascribe the formation of the schists to contact metamorphism. Such a case may be finely seen at Mt. Diablo. Here a dike of serpentine about 6.6^{km} long and 800^{m} wide extends in an east and west direction from the north flank of the mountain to near the east fork of Pine Creek. (See the geological sketch map of

Mt. Diablo.) On the south, this serpentine dike is flanked chiefly by the rocks of the Golden Gate series. On the north, at its east end, it is in contact with the shales of the Knoxville formation, and also, at its west end, in the upper drainage of the Arroyo del Cerro. At both points, it has effected no appreciable alteration of the Knoxville formation. In the Arroyo del Cerro drainage, the intrusive nature of this serpentine is beyond all question. The shales here stand nearly vertically with a strike in the neighborhood of the serpentine, approximately north and south, and a narrow apophysis of the main dike extends north into these shales for nearly one mile. This dike is cut by the Arroyo del Cerro and smaller streams, and in the ravines of these streams the dike nature of this serpentine apophysis can be clearly seen. The accompanying geological map shows the serpentine dike here described with the narrow apophysis extending north into the Knoxville shales. The area of the Golden Gate formation (*m*) in reality includes considerable masses of igneous rocks, chiefly metabasalt and serpentine. Thus the north peak is composed of a metabasalt which is said by Ransome to exhibit a spheroidal structure.

The Golden Gate series at Mt. Diablo, as elsewhere, however contains large amounts of igneous material which would more readily undergo recrystallization than the argillaceous and siliceous material of the Knoxville formation. It seems, therefore, possible that any contact metamorphism which the original peridotite of the serpentine dike might exert, would show more pronounced effects on the sediments of the Franciscan or Golden Gate series than on the material of the Knoxville formation. In addition to the large dike there are smaller masses of serpentine at various points along the flanks of the mountain. Glaucophane-schist is found near some of these serpentine croppings; in some cases exactly alongside of them; in other cases, it is not at the contact, but forms isolated croppings along with green amphibole-schists and micaceous schists. It would be unwise to insist that these schists have not resulted from the metamorphism of igneous material, by intrusive igneous masses, but it

GEOLOGIC MAP OF THE VICINITY OF MOUNT DIABLO, CALIFORNIA.

appears to me, in view of the foregoing facts, that it is yet to be demonstrated that these schists are the result of contact metamorphism of the peridotite intrusions. In any case, it seems clear that the glaucophane-schists and the green amphibole, garnet, and micaceous schists associated with them, are all caused by the same kind of metamorphism.

An investigation of the geology of the Bidwell Bar quadrangle, in the northern Sierra Nevada, has brought to light the existence of large areas of magnesian schists, associated with serpentine. These magnesian schists are composed of talc, chlorite, and various amphiboles, among which are prominent certain colorless amphiboles approximating to edenite and gedrite in composition. The microscopic investigation of these rocks clearly shows that these magnesian schists are alteration products of rocks of the same general nature as those which form the serpentine; that is to say, of rocks of the pyroxenite-peridotite family. The serpentine itself, no doubt, was largely formed from those masses rich in olive or rhombic pyroxene, and the various schists from aluminous pyroxenic facies of the magma. Many of these masses form croppings in and along serpentine masses, but they also form isolated areas of considerable extent. To conclude that any of these schists were formed by contact metamorphism would certainly in this case be erroneous, for not only can their composition be accounted for by supposing them to be alteration products of various pyroxenes, but their formation from these pyroxenes can in many cases be seen in the thin sections of the rocks.

If, as thought by Fairbanks, the Franciscan or Golden Gate series is older than the Knoxville, its generally hardened and altered character may have been the result of a pre-Knoxville metamorphism; for the beds, which have been determined as Knoxville, are nowhere much altered. It may then be advanced as a working hypothesis that the entire schist series of the Golden Gate formation was formed before the deposition of the Knoxville, and before the intrusion of at least some of the serpentine. If this be true, pebbles of some of these schists should

be found in the conglomerates of the Knoxville formation. Such conglomerates were observed at Knoxville, in Napa county. When making a geological map of the Knoxville quicksilver district for Dr. Becker, I collected some pebbles from these conglomerates, and later published[1] a few notes concerning them. As the characteristic fossil of the Knoxville formation (Aucella) occurs in this conglomerate, there can be no doubt concerning its age. The pebbles are of various porphyries, including soda-syenite porphyry and augitic porphyries and fine cherty pebbles, indistinguishable from the rocks called phthanites by Becker, radiolarian cherts by Lawson, and jaspers by Whitney and Fairbanks. A thorough investigation of these conglomerates will, perhaps, bring to light pebbles of some of these schists, the origin of which is ascribed to contact metamorphism and thus make certain their pre-Knoxville age. This being established, it would at least be certain that these rocks, if formed by contact metamorphism, were not formed by the serpentines which are found intruded into the Knoxville formation.

To the southeast of Coulterville,[2] in Mariposa county, and at other points, there are dikes of soda-feldspar, which are frequently intruded along the contact of serpentine masses with other rocks. These soda-syenite dikes, where altered, often contain blue amphibole in varying amount. Some of this may be primary, but part of it is secondary, The formation of glaucophane-schists (soda-amphibole) from crushed rocks containing much albite (soda-feldspar) seems quite possible. This is heightened by the finding by Ransome of white bunches composed of albite, in association with the glaucophane-schists on Angel Island. The suggestion of such an origin for the glaucophane-schists of the Coast Ranges should not, however, be taken too seriously.

Fossils being rare in the Golden Gate formation, all localities where remains have been found are worthy of note. About one mile (1.6 klms.) northeast of the summit of the north peak

[1] Am. Geol., Vol. XI, May 1893, p. 316.

[2] 17th Ann. Rept., U. S. G. S., Pt. I, p. 729.

of Mt. Diablo, in a ravine above the house of young Ben Dixen, fossils were found by Mr. F. M. Anderson, a student at the University of California, to whom I am indebted for the information. In company with Dr. Merriam, I visited this locality in 1897. We found more fossils there in thin, shaly layers in the hardened sandstone of the Golden Gate formation in a ravine above the house. This ravine heads just northeast of the north peak, and has a northeasterly course to about the fossil locality, where it turns sharply to the east. We collected some lamellibranchs here, which were not, however, specifically determinable. The sandstone is much intersected with fractures and can be readily broken out. This locality will probably afford more material, if carefully worked. Dr. T. W. Stanton, who saw Mr. Anderson's fossils, thought that the forms belonged to the *Cyprinidæ* or *Veneridæ*, but was unable to express a positive opinion concerning them.

The San Pablo formation. — At Kirker Pass,[1] north of the Mt. Diablo, south of the mountain at the Railroad Ranch reservoir, and at Corral Hollow, there are beds containing large amounts of volcanic detritus, as well as fossil shells and plant remains. The beds at Kirker Pass and Corral Hollow were first made known through the investigations of the State Geological Survey, under Professor Whitney. At a later date I visited the three localities above named and collected fossil plant remains at all of them, and fossil shells at two of them. The plant remains were studied chiefly by Professor Lesquereux, who assigned some of them to the Pliocene and others to the Miocene. The fossil shells were examined by Dr. Dall, who considered them to indicate a Pliocene age. Dr. Gabb had previously collected quite a series of fossil shells at Kirker Pass, and on that basis called the beds Pliocene.

In October 1897, in company with Dr. J. C. Merriam, I again visited Kirker Pass, and we collected there fossil shells and

[1] This pass is named after a Mr. Kirkwood, but the name Kirker having been used in geological literature for a long period, it is perhaps inadvisable to change the name to Kirkwood Pass.

plant remains, and I am indebted to Dr. Merriam for the following list of marine fossils from the Kirker Pass locality:

Fossils from San Pablo formation near Kirker Pass, north of Mt. Diablo, Contra Costa county, California. Collected by Gabb, Turner, and Merriam.

1. *Astrodapsis whitneyi* Rémond.
2. *Astrodapsis tumidus* (?) Rémond.
3. *Pseudocardium gabbi* Rémond.
4. *Ostrea Bourgeosii* Rémond.
5. *Ostrea titan* Rémond.
6. *Pecten pabloensis* Con.
7. *Pecten* (*Liropecten*) *crassicardo* Con.
8. *Cyrena californica* Gabb.
9. *Tapes staminea* Con.
10. *Tapes staleyi* (?) Gabb.
11. *Dosinia ponderosa* Gray.
12. *Gari alata* Gabb.
13. *Standella falcata* Gld.
14. *Saxidomus squalibus* Dash.
15. *Cardium blandium.*
16. *Macoma nasuta* (?) Con.
17. *Solen* sp.
18. *Mytilus* sp.
19. *Modiola* sp.
20. *Zirphœa* sp.
21. *Littorina remondi* Gabb.
22. *Littorina planaxis* Phil.
23. *Trophon ponderosum* Gabb.
24. *Ranella californica* Hds.
25. *Purpura saxicola* Val.
26. *Lunatia lewisii* Gld.
27. *Crypta grandis* Midd.
28. *Crepidula adunca* Sby.
29. *Calliostoma* n. sp. (?) Merriam.
30. *Ocinebra lurida* (?) Midd.
31. *Trochita filosa* Gabb.
32. *Trochita* n. sp. Merriam.
33. *Olivella boetica* Cpr.
34. *Bittium asperum* Cpr.
35. *Fusus* Gld.
36. *Purpura canaliculata* Duc.

This list contains 5 forms belonging to the Miocene, 2 (5?) forms belonging to the Merced formation, and 11 forms found elsewhere in the San Pablo formation.

There are 17 extinct and 14 living species, and the formation may, therefore, be regarded as of lower Pliocene age, on the basis of the ratio of the living and fossil forms.

In a recent paper,[1] on the Neocene sea-urchins, Dr. Merriam refers to the beds at Kirker Pass and similar beds at other points containing tuffs and volcanic ashes, as the "San Pablo formation." He considers the sea-urchins, belonging to the genus Astrodapsis, as particularly characteristic of this formation, inasmuch as he has not found them outside of it, and his information concerning the formations covers other localities besides those mentioned in this paper. This series of strata will then hereafter be spoken of as the San Pablo formation. In the bulletin, above referred to, Dr. Merriam concludes that this formation is of Middle Neocene age, including the top of the Miocene, and the base of the Pliocene. In my bulletin on Mt. Diablo, I called attention to the similarity of the plant forms in the San Pablo formation of the region about Mt. Diablo with the plant remains of the Auriferous gravels formation of the Sierra Nevada. The collections of the plant forms from the Coast Ranges are not sufficient to narrowly correlate the plant remains from the two regions, but it is clear that the marine fossil shells of the San Pablo formation furnish a more certain criterion for determining the exact horizon of the formation, than do the plant remains.

When the plant forms of the San Pablo formation have been collected in greater number and thoroughly studied a comparison can then be made between the floras of the Auriferous gravel series, and of the San Pablo formation, and the age of the auriferous gravels decided on that basis. As pointed out in an article on the Auriferous gravels,[2] it is certain that the fossil leaves collected from different localities in the Sierra

[1] Bull. Dept. Geol. Univ. of California, Vol. II, p. 116.

[2] American Geologist, Vol. XV, June 1895.

Nevada from the Auriferous gravels formation represent different horizons; nevertheless, no distinction has been made thus far by the palæobotanists, who have examined the different collections. It is, therefore, probable that, when studied, certain of these localities will be found to furnish a flora similar to that of the San Pablo formation, and other localities will furnish floras of a somewhat older date. In general, in recent years, the fossil plant remains of the auriferous gravels have been called Upper Miocene. It is more than likely that some of these localities are of Pliocene age. There is published herewith, a section of the San Pablo formation at Kirker Pass, north of

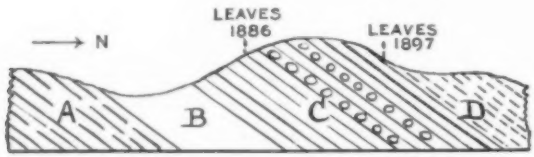


FIG. 1.—Section of the San Pablo formation on the Hyde Ranch, north of Mt. Diablo. The horizontal extent of the section is about 600 meters. The section, however, does not necessarily include the top or the base of the formation at this point. *A* = White shales and rhyolitic tuff; *B* = Fossiliferous sandstone; *C* = Andesitic tuff, sandstone, and conglomerate; *D* = Shale and pumice.

Mount Diablo. The horizontal extent of the beds shown in the section is 600 meters. The beds dip uniformly to the north at an angle of about 35° and thus have a thickness normal to the bedding of about 350 meters, or about 1150 feet. The section given above (Fig. 1) is drawn without reference to scale, merely to show the relations of the different members of the formation. The basal portion (*A*) of the section is composed of fine-grained white shales, and volcanic detritus, which Dr. Merriam has noted at other localities in the formation, and he regards this as its base. An optical examination of volcanic glass which forms certain layers in these white shales, shows the glass to be of rhyolitic composition. There is given below an analysis, No. 399, of a specimen of this glass. This analysis shows that the rhyolite has undergone leaching, having lost both alkali and silica, as is

very frequently the case with layers of volcanic glass and pumice. Overlying this basal volcanic series are some sandstone beds (*B*), which have offered the majority of the marine fossil shells from this locality. Lying upon fossiliferous sandstones are a set of blue beds (*C*), composed of volcanic conglomerate, tuff and sandstone. The tuffs and volcanic conglomerates are derived from andesite, containing hornblende and pyroxene. These andesitic tuff beds contain abundant silicified wood, and the first list of fossil leaves given below collected in 1886, came from a fine layer in this tuff series.

These leaves were studied by Lesquereux, who published a list of the species identified in the proceedings of the U. S. National Museum (Vol. XI, 1889, p. 35), as follows.

Fossil leaves from the San Pablo formation on the Hyde Ranch, collected in 1886.

Diospyros virginiana L, var. turneri, Lx.
Magnolia californica Lx.
Laurus, cf. *canariensis* Heer.
Virburnum, cf. *rugosus* Pers.
Vitis, sp. (?).

These are considered to be probably Pliocene, although on page 11 of the same publication, the same collection is referred to the Upper Miocene. These leaves come from a fine layer in the blue andesitic sandstones which form a higher horizon than the bed which afforded the most of the fossil shells given in the previous list by Dr. Merriam.

The leaves collected in October 1897, came from a bed conformably overlying the blue andesitic sandstones, and underlying the volcanic pumice represented by specimens 345 (Series D). Immediately underlying the leaf layer, is a light colored layer, containing specks of pumice in which are fossil shells. One of these, is an Astrodapsis, as determined by Dr. Merriam, which is considered as characteristic of the San Pablo formation. This second set of leaves came from a higher horizon of the San Pablo formation than those collected in 1886. The leaves collected in 1897 were referred to Professor F. H. Knowlton

of the National Museum, who reports as follows concerning them:

> Six species of plants are represented:
>
> Fern, probably *Pteris*, but very fragmentary.
> *Populus*, female Catkin.
> *Alnus*, fruits and leaves.
> *Castanea*, sp. leaf.
> *Vaccinum*, sp. single small leaf.
> *Arbutus*, sp. Numerous well-preserved leaves and fragments.
>
> I have not been able to identify any of the above mentioned material with anything from California. The forms all have a very modern aspect, the more abundant being the Arbutus, which is close to the living form.
>
> As to the age, I do not think there can be any doubt about their being Pliocene. They certainly cannot be older.

The conclusion of Professor Knowlton that the plant remains in 1897 are certainly not older than Pliocene, would not appear to conflict with the conclusion of Merriam as to the Middle Neocene age of the formation as a whole, inasmuch as these leaves came from near the top of the formation, as exposed near Kirker Pass. Overlying the plant remains above noted, are some layers of volcanic pumice (*D*), of which specimens were collected. An examination of this material under the microscope shows that it has been much altered by infiltrating waters, but that the glass has a rhyolitic composition, as indicated by its low index of refraction. A chemical analysis of one specimen, No. 345, shows, as does the analysis of No. 399, that the pumice has undergone leaching, resulting in a loss of silica and alkali. All of the plant remains obtained by myself at Kirker Pass came from the Hyde Ranch, and were collected in a field west of the road from Cornwall to Summersville. The locality of 1897, is on the north slope of a low hill, and about 430 meters south of the house of George South.

The San Pablo formation, at Corral Hollow, has afforded nineteen species of fossil plants. A few of which have been identified in the Auriferous gravels flora. The plant beds at Corral Hollow, from which the specimens came which I collected, underlie andesitic tuffs, and conglomerates, which are

quite like those of the San Pablo formation, in the Mount Diablo quadrangle. It is, therefore, likely that the Corral Hollow plant remains represent a somewhat older horizon than those collected near Kirker Pass.

ANALYSES OF RHYOLITIC TUFF FROM THE SAN PABLO FORMATION, BY WILLIAM VALENTINE.

	No. 339. Near base of San Pablo	No. 345. Near top of San Pablo
SiO_2	63.28	63.28
CaO	1.90	1.18
K_2O	2.44	0.78
Na_2O	1.82	0.56

The Merced formation of Lawson,[1] which has been referred to, is probably younger than the San Pablo and of Upper Pliocene age. The Merced formation is named from Merced Lake, in the vicinity of which the beds are extensively developed. It is probably identical with the Wild Cat series of Humbolt county, described by Lawson,[2] in which case the latter name should be dropped. As pointed out by Lindgren,[3] the correlation by Lawson on the Merced series with the Auriferous gravels formation is probably incorrect. It is far more likely that the Auriferous gravels series is in part contemporaneous with the San Pablo formation, and in part older than that formation.

H. W. TURNER.

[1] Bull. Dept. Geol. University of California, Vol. I, pp. 142–149.

[2] Bull. Dept. Geol. University of California, Vol. I, pp. 255–263.

[3] JOUR. GEOL., Vol. IV, pp. 904, 905.

STUDIES FOR STUDENTS.

THE DEVELOPMENT AND GEOLOGICAL RELATIONS OF THE VERTEBRATES.

II. AMPHIBIA.

THE *Amphibia* may be described as forms that live a portion of their lives, at least, in the water or in a condition fitted for an aquatic existence; the latter statement is necessary from the fact that some forms never live in the water, but develop external gills such as are found in the forms which do pass the larval stage as aquatic forms. All amphibians pass through a metamorphosis in which the external gills of the immature forms are lost and lungs developed. The skull presents some peculiarities; the whole base of the cranial region is covered by a large presphenoid bone that extends far forward as well as backward. In the more highly developed types of the vertebrates this bone occupies a minor position anterior to the basi-occipital. In many of the more primitive forms of the amphibians the bones of the cranial region are largely cartilaginous; the extremities of the long bones of the limbs are without the epiphyses, or separate ossifications, that are found in the mammals, and the ribs are attached each to a vertebra instead of intervertebrally as in the higher forms.

That the *Amphibia* were derived from the *Pisces* is without question, but from what branch of the piscine stem they were developed has been the subject of much discussion. For a long time they were supposed to be derived from the *Dipnoans*, and from forms that were very close to the existing genera of the order. This idea is still supported by Haeckel (*Systematische Phylogenie der Wirbelthiere*; Berlin, 1895). In discussing the question, Baur said (The Stegocephali: a phylogenetic study;

Anatomischer Anzeiger, Band XI, Nr. 22, 1896, p. 659) "That the *Stegocephali* (the most primitive of the amphibia) did take their origin from a group of fishes is evident. The question to examine is: Which was this group?"

"In the Devonian preceding the Carboniferous, where the *Stegocephali* first appear, we have the following groups of fishes: The *Elasmobranchii* — including the *Holocephali* — *Ostracodermi*, *Dipnoi*, *Crossopterygii* and *Chondrostei* (this last group corresponds to the *Actinopterygii* of the present studies). The *Elasmobranchii* have no dermal ossifications in the skull, they are therefore out of the question; the *Ostracodermi* have, of course, nothing to do with the *Stegocephali;* we also can exclude the *Chondrostei* represented by *Cheirolepsis*. Only the *Dipnoi* and the *Crossopterygii* remain.

The dentition of the *Dipnoi* is already so much specialized in the Devonian, that it is impossible to derive the *Stegocephali* from them. We have now to consider the *Crossopterygians*. The *Crossopterygii* were established by Huxley, in 1861, to contain the living *Polypteridæ* of Africa and the extinct *Holoptychidæ*, *Rhizodontidæ*, and *Osteolepidæ*, having lobate paired fins with an endoskeletal axis, more or less fringed with dermal rays. The *Crossopterygii* are the most typical fishes of the Devonian. There is no difficulty in homologizing the premaxillaries, nasals, frontals, parietals, prefrontals, and postfrontals in the *Crossopterygii* and the *Stegocephali*." Here the author proceeds to prove from the course of the grooves upon the skulls of certain of the more primitive of the fishes and the amphibians, which mark the course of the sensory tracts of nerves in the living form, the homology of the skull bones of the two groups and the close connection that exists between them.

In a further discussion of the homology of the ribs he concludes that the "ribs of the eldest *Batrachia*, the *Stegocephali*, are not homologous with the ribs of the *Dipnoi*; therefore the *Dipnoi* cannot be the ancestors of the *Stegocephali*," and "the *Batrachia* must have developed from the *Crossopterygii*."

The *Amphibia* may be classified as follows:

Class, AMPHIBIA.
- Order, *Labyrinthodontia.*
  - Suborder, *Branchiosauria.*
  - *Microsauria.*
  - *Aistopoda.*
  - *Labyrinthodonta vera.*
    - a, *Embolerimi.*
    - b, *Rachitomi.*
    - c, *Labyrinthodonti.*
- Order, *Coccilia.*
  - *Caudata* (*Urodela*).
  - Suborder, *Salamandrina.*
  - *Ichthyoidea.*
- Order, *Ecaudata* (*Anura*).
  - Suborder, *Arcifera.*
  - *Firmisterna.*
  - *Aglossa.*

It is with the first of these orders that the student of palæontology is the most concerned, as they were the predominant forms of life during the Carboniferous time and even during the first part of the Mesozoic. The other orders did not assume any importance before the beginning of the Tertiary, and only one of them, the *Caudata*, appeared as early as the Cretaceous.

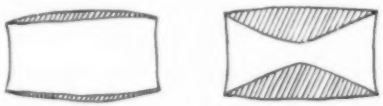
The earliest trace of amphibians is found in the Devonian rocks of Warren county, in Pennsylvania, and consists of tracks of some large labyrinthodont that Marsh has called *Thinopus antiquus* (*Am. Jour. Sci.*, 1896). No other trace of the *Amphibia* has been found in rocks earlier than the Carboniferous, but with the appearance of that time a large number of forms were developed that in the variety of their forms and the degree of their specializations rivaled the development of the reptiles of later times. To this large group of semi-aquatic forms Huxley gave the name *Labyrinthodonta* in 1863; five years later Cope gave the name *Stegocephali* to the same group. The latter name is used the most commonly in this country.

In external appearance the *Labyrinthodontia* were very similar to the existing tailed amphibians, the body was long in some cases and in others more stout and heavier; the skin was naked,

but in most cases, on the ventral surface, at least, protected by the development of small dermal ossicles of bone; the legs were in most of the forms rather short and weak, and in some cases were entirely atrophied as in the recent snakes; the bones of the more primitive forms were quite largely cartilaginous, the carpus and the tarsus of some forms being almost entirely so, and even the long bones of the limbs and the bones of the skull were incompletely ossified; the skull was completely roofed over by dermal bones developed in the skin of the head, leaving only five openings in the skull, the two nostrils, the orbits, and the pineal foramen, the last a single opening on the upper surface of the skull. The teeth of most of the forms, and of the more highly developed forms of the Trias especially, are notable for the peculiar infolding of the enamel, giving the internal structure of the tooth a most complicated appearance.

The structure of the spinal column in the various forms is of especial interest, as it parallels in the first stages the history of the spinal column of the fishes and takes the process a few steps farther. In all of the *Labyrinthodontia* the notochord is to a greater or less extent persistent. In the simplest of the *Amphibia* the chord is very large and the vertebræ are represented by small plates arranged in pairs on the upper and lower surface of the chord; to these plates are attached the spinuous processes and the hæmal arches that protect respectively the spinal chord and the nutrient arteries (in the amphibians the hæmal arches are complete only in the caudal region). The next stage in the development of the column is the union of the plates, on the upper and the lower side of the chord, to form a complete cylinder that incloses the chord. The cylinder is of equal bore throughout and does not constrict the chord or tend to divide it up into segments. These two conditions are found only in the most simple of the amphibians and are well illustrated in the immature and mature forms of the *Branchiosauria* (Fig. 1, *A*). The next step is the thickening of the walls of the middle portion of the cylinders that surround the notochord so that the bore is very small at the center, while at the anterior

and the posterior ends the bore is still full size; this tends to divide the notochord at the middle of each vertebra and to leave intervertebral segments. This condition of the vertebræ, with deep cups at each end, is called "biconcave." It is the same condition that is found in the primitive reptiles, and the closing of the notochordal canal and the filling up of either the anterior or the posterior cups of the vertebra would complete the development of the highest type of the reptilian vertebra. (Fig. 1, *B*.)



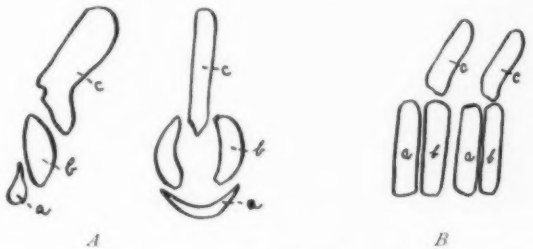
A *B*

FIG. 1.—*A* Section of Branchiosaurian vertebræ showing size of notochordal canal; *B* Section of microsaurian vertebræ showing contraction of notochordal canal.

Another type of vertebræ that was developed by the amphibians seems to be somewhat more primitive than the last described, and also to be somewhat off the line of direct development. There were four distinct pieces, an upper, that supported the spinuous process, a pair, of small size, that stood on each side of the notochord, the pleura-centra, and a crescent shaped piece on the lower side, the intercentrum, that occupies the position of the plate supporting the hæmal arch in the simpler vertebræ. Upon the condition of these four pieces were established the divisions of the suborder *Labyrinthodonta vera*. When the pieces are all separate and in the condition described above, the forms are called rachitomous; the two lateral pieces may fuse and form a ring around the notochord, and at the same time the intercentrum develop from a crescent-shaped piece into a perfect ring, so that each vertebra is represented by two complete rings, this is the embolomerous stage; in the third condition the four pieces fuse to form a solid vertebra; this is most common in the caudal region and may be present there, while in the anterior portion of the column the

four original pieces are still separate. This is the stereospondylus condition (Fig. 2).

Another line of development that is quite closely connected with the geological history of the animals is the development of



A *B*

FIG. 2.—*A* Rachitomous vertebra. *B* Embolomerous vertebra. *a* Intercentrum; *b* Pleurocentrum; *c* Neural spine.

the shoulder girdle. In the more primitive forms, especially the *Branchiosauria* of the Permian, the bones of the shoulder region were largely cartilaginous and were small in size; as we progress through the Carboniferous and into the Triassic time the bones become larger and firmer, until in the latest of the Triassic forms they form a close dermal armor over the underside of the thoracic cavity. In the majority of the forms there is developed in the skin of the abdomen and the lower side of the legs as well, a large number of small bony ossicles that served as a protection for the posterior part of the body. The history of these is also closely connected with the geological progress of the animal; in the earliest forms the ossicles are small and numerous; as the forms progressed the ossicles became larger and less numerous.

BRANCHIOSAURIA.—This is the most primitive group of the *Amphibia*. The forms were all small and salamandriform; there was a short tail, and the limbs were short and weak. The vertebræ in the adult form were barrel-shaped as already described and in the immature form composed of two separate pieces, an upper and a lower. There was no plication of the enamel of

the teeth as in the more advanced forms. The bones were largely cartilaginous, the tarsus and carpus and the bones of the occipital portion of the skull entirely so. The ventral surface of the body was protected by a large number of dermal scutes.

Most of these forms are known from the Rothliegende of Germany, but specimens have been found from the same horizon and from the Upper Carboniferous of France and Ohio; from the German region a very large number of forms have been taken in the most excellent state of preservation so that it has been possible to study not only the adult forms, but the young stages as well and to make out the various steps in the metamorphosis of the individual. Credner studied a large series of forms from about 30^{mm} to 120^{mm}, and made out all the stages of development, the growth of the external gills, their loss, and the assumption of the adult form.

Branchiosaurus is the best known genus of the suborder and a description of it may serve as an illustration of the whole group. The head was comparatively large and rounded in front; the edges of both jaws were lined with numerous small, conical teeth; the skull was completely roofed by dermal bones, and the surface of these bones show a very strong sculpture. The condition of the vertebræ, the carpus and tarsus, and the bones of the occipital region was as already described; the limb bones were cartilaginous at the extremities. The eyes were rather large and were protected by bony plates developed in the sclerotic coat, the "sclerotic plates." The whole animal must have presented much the same appearance as one of the modern salamanders and had, probably, much the same habits, never going any great distance from the water.

Melanerpeton, *Apateon*, and *Pelosaurus* from the same locality and horizon as the *Branchiosaurus*, were very similar in appearance, differing only in minor skeletal characters.

Protriton is a form described from the Rothliegende of Autun, in France, and is regarded by some as identical with the early stage of *Branchiosaurus* as it has the external gills and other characters of the larval forms of that genus.

Amphibamus and *Pelion* are from the Carboniferous beds of Ohio. In the first genus the body was rather long; the legs were short with the posterior pair somewhat the largest; the head was rather large and rounded; the teeth were numerous and set close together. *Pelion* had a rather shorter and broader head, the legs were longer and better developed.

MICROSAURIA.—These were in many ways the most highly developed of the *Labyrinthodontia;* the vertebræ, as already explained, approached more nearly the modern type of reptilian vertebræ than any of the group. Their advanced position is evidenced by other parts of the body as well as the vertebræ; all the bones of the body are more perfectly ossified; the bones of the skull are set more firmly together, and the limbs are longer and stronger so that the animal was able to raise the body from the ground, and must have possessed a considerable degree of agility. The carpus and tarsus were ossified, and there were well-developed claws on the feet. Many remains have been found in the trunks and stumps of fossil trees in the working of the quarries in the South Joggins coal region of Nova Scotia, showing that the animals were to some extent at least arboreal in their habits, and that they had reached a freedom of motion and a range of habitat far in advance of that of the other amphibians of the time. It is to this group that we must look, in all probability, for the direct ancestors of the reptiles. The name *Sauromorpha* has been given to the group in recognition of the close relation between it and the *Reptilia*.

Hylonomus and *Hylerpeton* are forms from the South Joggins quarries of Nova Scotia. They were rather elongate in form, with a lizard-like appearance. The vertebræ were well developed, and the whole body was covered with bony scutes instead of the ventral surface only as in most of the forms. The teeth were smooth at the base, but near the top the dentine was somewhat plicated. These were among the best developed of the amphibian forms. It is interesting to note the occurrence of the same genus, *Hylonomus*, in Nova Scotia and in Bohemia.

From the Carboniferous rocks of Ohio, near Linton, have

been taken a very large number of the *Microsauria*. Among the most common are *Tuditanus*, *Leptophractus*, *Colosteus*, *Osteocephalus*, and *Ptyonius*.

Tuditanus was rather small form with a short and broad head and the orbits located far forward. There seems to have been a lack of the dermal scutes on the ventral surface and their place was taken by three pectoral shields that exhibit a strong sculpture on the external face; they were the expanded clavicles and the interclavicle. The whole animal was about three to four inches long.

Colosteus reached a length of a foot in some cases. The form was elongate with rather short legs. There were three pectoral plates as in *Tuditanus* as well as a well-developed armor of fine scutes. The teeth were not of equal size, the anterior ones being much the larger.

Ptyonius exhibits a very high degree of specialization. The body was long and serpentiform, and the limbs had entirely disappeared so that the animal had reached the same stage of development as the modern snakes. One very peculiar thing is to be noticed about this form; the distal edges of the transverse processes and neural-spines were fluted or folded so that they present a fan-like appearance.

Leptophractus was by far the largest of the Ohio forms, having about the size of an alligator. Only portions of the skull are known but enough to show that the skull was rather elongate, and that the teeth had the dentine folded as in the true labyrinthodonts. Near the anterior end of the jaw there was a large caniniform tooth.

Osteocephalus resembled in some respects *Ptyonius*. The body was long and snake-like, and the skull was very acuminate. The anterior pair of limbs were absent or rudimentary, and the posterior pair were very short. The three pectoral plates found in most of these forms were absent in this one, and their place was taken by a profusion of slender bony rods that ran obliquely inward and forward covering the whole ventral surface. There were no dermal scutes as in the other forms.

The Carboniferous rocks of Nyran in Bohemia have yielded many forms belonging to the same group, among them are *Hyoplesion*, *Orthacosta*, *Microbrachis*, *Keraterpeton*, and *Urycordylus*.

Hyoplesion is quite similar in structure to *Hylonomus* of the Nova Scotian region, and is regarded by some authorities as synonymous with it.

The other forms do not present any striking peculiarities except *Urycordylus*, which has the same peculiar fluting sculpture of the ends of the transverse processes and the neural-spines as *Ptyonius* and *Osteocephalus* of North America.

Aistopoda.—This group was very similar in some respects to certain forms of the previous group. The limbs were entirely atrophied as in *Ptyonius;* in addition to this character the parietal and frontal bones were fused into one, and the ribs showed a very peculiar bifurcated condition near the distal end.

Dolichosoma from the Carboniferous rocks of Ireland and Bohemia was quite long, having as many as 150 vertebræ, a number equaled only among the snakes. The skull was small and tapered to a point in front, and there was no evidence of dermal armor.

Ophiderpeton from the Carboniferous of Ireland had a somewhat shorter and broader skull than *Dolichosoma*; the ventral surface of the body was covered with small scutes; the whole animal was about 40–50^{cm} long, and there were in the neighborhood of 100 vertebræ.

Phlegethonia and *Molgophis* are two forms from the same region in Ohio as the *Microsauria* mentioned. They have been considered as synonymous with *Dolichosoma*, which, if true, would indicate a peculiarly wide range for such a specialized form.

Labyrinthodonta Vera.—As before stated this group is made up of three subgroups, the *Rachitomi*, the *Embolerimi*, and the *Labyrinthodonti*. The first subgroup is found only in the United States.

Rachitomi.—In this division, as in the others of the same group, there were many very large forms. The skull was com-

pletely covered with thick and heavy membrane bones that showed a deep and intricate sculpture; the whole head was flattened and either very broad in proportion to its length or long and crocodilian in aspect; the base of the skull was in large part cartilaginous; the limbs were short but very strong, and there were five digits on each foot: the tail was of moderate length; the pelvic and pectoral girdles were strong and broad; the pelvis was peculiarly like that of the modern frog in many of the forms; the vertebræ were made of several distinct pieces as already described. The known forms of the group are almost entirely from the Permian rocks of Europe, the East Indies, and North America.

Archægosaurus from the Rothliegende of Germany was rather crocodilian in aspect; the head was long and slender and joined to a rather elongate body. In youth the animal was furnished with external gills as in the modern salamanders, which were probably shed when the animal reached maturity; the dentine of the teeth was arranged in a radial manner the first step towards the intricate folding of the enamel in the more advanced forms; the clavicles and the interclavicle were broad and strong covering to some extent the lower surface of the thorax.

Chelydosaurus from the Rothliegende of Bohemia was shorter than *Archægosaurus* with a broad head and large orbits; the dermal bones covering the head were sculptured in a peculiar radial fashion. Nearly every portion of the skeleton is known, and the preserved bones show that the animal was rather in advance of the majority of the forms of the time as they are almost entirely free from cartilage.

Discosaurus is a closely related form from the same horizon in the neighborhood of Dresden.

Actinodon and *Euchirosaurus* are from the lower Permian (Rothliegende) of France. The first was much like *Archægosaurus*, but the head was shorter and more triangular in outline; the length of the skull was about 18^{cm}. The second genus is less well known than the first, but is remarkable for the strength

and perfection of the limb bones, especially the articular surfaces which, as a general thing, are not well developed even in the recent amphibians.

Melosaurus from the Keupfer sandstone of Orenbourg in Russia was, so far as the imperfect specimen can be interpreted, quite similar to *Archægosaurus;* it has been suggested that it may be the same genus; if this is true, it would indicate a very wide range of distribution for the animal.

Trimerorachis and *Eryops* are from the Permian deposits of Texas in the United States. Only the lower division of the Permian, the Wichita division of the Texas geologists, has yielded any vertebrate fossils, but in this horizon there is a somewhat abundant fauna of amphibians, reptiles and fishes. In the neighborhood of Danville, in eastern Illinois, there have been found remains of the same amphibians that are found in the Texas deposits; the area is only a small one and is regarded as the course of an old river that has cut its bed through the underlying Carboniferous rocks. Some fragments of the same animals have been found in New Mexico. Of the genus, *Eryops*, Cope, the describer says, "this is the largest of American batrachians, the skull measuring a foot wide by eighteen inches long. It was very abundant constituting with the reptilian genus, *Dimetrodon*, the most prominent type of the Permian fauna in this country. The vertebral column is slender when compared with the size of the limbs and especially the head." Of the genus *Trimerorachis* he says, "the head of *T. insignis* is wide, flat and rounded, and its superior surface is strongly wrinkled. The lyriform mucous grooves do not extend behind the orbits. This was an abundant species during the Permian time in Texas, and probably possessed aquatic habits."

Acheloma and *Anisodexis* are forms from the Permian of Texas that are less well known than the foregoing and are perhaps synonymous with *Eryops*.

EMBOLERIMI.—These are perhaps the most interesting of the *Labyrinthodontia*; as already indicated they are distinguished by the fact that the vertebræ are made up of two rings formed by

the upward growth of the lower segment of the vertebra of the rachitomous type and the downward growth of the upper segment and its union with the two lateral segments.

Cricotus, the best known form is from the Permian deposits of Texas, the same locality as the rachitomous forms. It was rather long and crocodilian in aspect and the head was covered with the same kind of membrane plates as in the other genera but they were devoid of sculpture; the orbits were large and placed far forwards.

Diplovertebron from the Gaskohle of Bohemia is known only from fragments of the skull, limb bones and vertebræ, but the vertebræ show the same structure as *Cricotus*.

Labyrinthodonti (Stereospondyli).—These are the very large form that appeared at the end of the Palæozoic and reached their greatest development during the Triassic. They possessed complete biconcave vertebræ with a central foramen for the passage of the notochord. The most peculiar feature of the group, is the arrangement of the outer layer of the teeth; instead of the usual smooth layer the enamel is thrown into the most complicated folds so that a cross section of the tooth has an almost dendritic appearance. In other features than the teeth the group evinces its advanced position among the amphibians; the bones of the skull are all well ossified and the base of the skull is composed entirely of bone instead of being partly cartilaginous as in the preceding groups; there is no trace of the grooves on the upper surface of the skull to mark the position of the sensory tracts; the thoracic region is completely protected by the development of the clavicles and the interclavicle into large and strong plates that are tightly joined together; the posterior abdominal region is also protected by the expansion of the bones of the pelvis though not to the extent reached in the anterior girdle; the limb bones are all well ossified and the carpus and tarsus were entirely bony; the feet were provided with strong claws.

Trematosaurus from the Buntersandstein, near Bernberg, in Germany, was one of the smaller forms; the skull was about

24^{cm} long and rather narrow, giving the skull a rather crocodilian appearance; the edges of the maxillaries were lined with small, nearly equal sized teeth that were opposed to a similar series on the lower jaw; besides the rows of teeth on the maxillaries there were a number of larger teeth on the palatines and the vomer, covering the roof of the mouth with a strong dentition.

Metoposaurus (*Metopias*) from the Keupfer sandstone of Germany was nearly twice as large as *Trematosaurus*, the skull measuring about half a meter. The shape of the skull was much the same as in *Eryops* of the American Permian, being broad and stout, depressed from above downwards and showing a decided sculpture on the outer surface of the bones; the genus is peculiar for the very strong development of the pectoral shields, the interclavicle is a broad, diamond-shaped bone on either side of which are joined the clavicles that are also developed into broad plates, the whole covering the ventral side of the anterior portion of the body; all three of the bones exhibit a rugose outer surface.

Capitosaurus from the same locality and horizon as *Trematosaurus* was nearly as large as *Metoposaurus;* the orbits were small and elliptical; the nares large and located far forward; the extremity of the snout was broad and blunt. The same dentition is found in this as in the previous form, a series of small teeth on the edges of the upper and lower jaws and a few large tusk-like teeth on the palatines and the vomer; the surface of the skull shows a slight trace of the sensory canals and the bones are deeply pitted with grooves radiating outward to the edges of the bone.

Mastodonsaurus from the Lettenkohl, the lower division of the Keupfer, reached the largest size of any of the *Labyrinthodonti;* the skull in some specimens reaching a meter in length. The skull was rather triangular in outline; the eyes were small and the nares located far forwards; the grooves marking the course of the sensory tracts are very distinct; there was a double instead of a single row of small teeth on the edges of the upper and the lower jaws and there were two or more enlarged

palato-vomerine tusks on each side. The whole animal had a probable length of about ten feet, the head being disproportionately large.

Labyrinthodon from the same horizon as the previous forms is, according to Lydekker, a synonym of *Mastodonsaurus*. It was described by Owen from a single tooth and the name was founded on the peculiar folding of the dentine. As most all of the *Labyrinthodonti* have the same character the distinction fails; it is as well however to know the genus as the name is a common one in the text-books. (See Owens, *Odontography*, Pl. LXIII. Fig. 1, for a picture of the structure of the labyrinthodont tooth.)

Nyrania from the Permian of Bohemia and *Bothriceps* and *Micropholis* from the Permian of South Africa are less well known foreign genera. Certain imperfectly preserved remains have been collected from the rocks of the Newark system of Pennsylvania and North Carolina. *Eupelor* is the name of the small form from Pennsylvania, and *Pariosteigus* and *Dictyocephalus* from the Carolina region. Quite recently a tooth has been described from the Upper Carboniferous of Kansas, and referred to the genus *Mastodonsaurus;* if the determination is correct this indicates a rather peculiar distribution for the genus as it is unknown from the English deposits, though quite common on the continent.

Below is a summarized list of the most important forms of the *Labyrinthodontia* with their geological range and habitat so far as known.

LABYRINTHODONTIA.

Branchiosauria.

Branchiosaurus, Rothliegende, Germany.
Melanerpeton, *Apateon* and *Pelosaurus*, Rothliegende, Germany.
Protriton, Rothliegende, France.
Amphibamus and *Pelion*, Carboniferous, Ohio.

Microsauria.

Hylonomus and *Hylerpeton*, Carboniferous, Nova Scotia.
Tuditanus, *Osteocephalus* and *Colosteus*, Carboniferous, Ohio.
Hyoplesion and *Microbrachis*, Carboniferous, Bohemia.
Lepterpeton and *Keraterpeton*, Carboniferous, Ireland.

Dolichosoma and *Ophiderpeton*, Carboniferous, Ireland.
Molgophis? and *Phlegethonia?*, Carboniferous, Ohio.

Labyrinthodonta vera.

Rachitomi.

Archægosaurus, Rothliegende, Germany.
Chelydosaurus, Rothliegende, Bohemia.
Actinodon and *Euchirosaurus*, Rothliegende, France.
Trimerorachis and *Eryops*, Permian, Texas.

Embolerimi.

Cricotus, Permian, Texas.
Diplovertebron, Permian, Gaskohle, Bohemia.

Labyrinthodonti.

Trematosaurus, Buntersandstein, Germany.
Metoposaurus, Keupfer, Germany.
Capitosaurus, Buntersandstein, Germany.
Mastodonsaurus, Keupfer, Germany.
Micropholis and *Bothriceps*, Permian, South Africa.
Eupelor, *Pariosteigus*, and *Dictyocephalus*, Triassic, Pennsylvania, and North Carolina.

Besides the remains of fossil forms the rocks of the Carboniferous and Triassic times have yielded a large number of tracks, made when the animal walked across some mud flat. These tracks have received the name of *Ichnites*. Such tracks in the Carboniferous rocks are known from Kansas and Nova Scotia. Most of the tracks however occur in the Triassic rocks; the red sandstone of the Connecticut River Valley has yielded a large number. Prominent among them is the form described as *Brontozoum*. These are enormous tracks, the middle digit having a length of 12.5 inches and the whole foot 14 to 18 inches. The whole animal must have been twelve to fourteen feet long.

Anisopus from the same locality had the hind foot nearly twice as large as the front foot.

Anomœpus had five digits on the front foot and only three on the hind foot. (This form may very possibly have been reptilian).

Chierotherium or *Chierosaurus* from the Buntersandstein of Europe was about half the size of *Brontozoum*. The hind foot

was about twice the size of the front foot, and there were five digits on both. The same form is known from the Triass of Cheshire in England.

It is altogether probable that many of these tracks belong to forms already described from parts of the skeleton but until some one shall be so fortunate as to discover the skeleton and the tracks together it will be impossible to detect the synonymy. It has been suggested that the tracks referred to as *Cheirosaurus* belong either to *Capitosaurus* or to *Trematosaurus*.

The whole of the order *Labyrithodontia* dies out in the Triassic but the degree of specialization to which the members of the order attained bears ample witness to the important part they played in the fauna of the Carboniferous and the first part of the Mesozoic. Only by the demands of a most severe struggle for existence could there have arisen within the limits of a single order the necessity for the great divergence of forms that we find among the *Labyrinthodontia*. The wide distribution of the forms also bears witness to their prominence, forms being known from the East Indies, South Africa, Europe, England, and North America.

The remaining orders of the amphibians are unknown before the Cretaceous.

The *Caudata* (*Urodela*) are lizard-like, tailed animals with a naked skin and with or without persistent external gills. The skull lacks certain of the bones found in the posterior part of the skull of the *Labyrinthodontia*, as the supratemporal, supraoccipital, and the postorbital. The vertebræ are complete in a single piece. There are two suborders of the *Caudata*, the *Ichthyoidea*, in which the vertebræ are biconcave, and the *Salamandrina*, in which they are opisthocoelus or concave behind and convex in front. The common *Siren*, *Proteus*, and *Menobranchus* are living representatives of this order. Among the fossil forms perhaps the most interesting is the *Andrias* from the fresh water Miocene of Œningen. This form was described as early as 1726 by Scheuchzer, who considered the imperfect skeleton which he had as the remains of an antediluvian man, and gave

to it the name "homo diluvii testis et theoscopos." The same form was afterwards described as fish and as a lizard, until finally its true nature was made out. The form reached a length of about four feet in the largest specimens and was one of the largest of the *Caudata*. In most of its skeletal characters it was very similar to the modern *Menobranchus*.

Megalotriton is one of the *Salamandrina* from the Upper Eocene of France. It was of considerable size, judging from the vertebræ and the detached bones of the limbs. No complete skeleton has been found.

The *Anura* (*Ecaudata*) are little known from the fossil forms. They appear in the Tertiary with almost as many genera and species as at the present time, and there has been little change in the forms.

The origin of the modern forms of the amphibians is not known. Zittel says of these forms that they can in no sense be derived from the labyrinthodonts, for between these and the modern forms there exists not only a great morphological gap, but a great break in the geological record as well.

III. REPTILIA.

PAREIASAURIA.—The simplest of the *Reptilia* differ very little from the *Amphibia*. There is little in the structure of the *Pareiasauria* that might not belong to the *Labyrinthodontia* except the arrangement of the bones forming the base of the skull. Add to this that the animal did not undergo a metamorphosis from a water to a land form and the list of differences is complete. All during the Carboniferous time the conditions had been growing better and better fitted for the existence of purely terrestrial, air-breathing forms, and at the end of that time, if not, as there is reason to think, some time before, there appeared the forerunners of the great tribe of reptiles. As has been indicated, the *Microsauria* were in all probability the direct ancestors of the reptiles, but the evidence of the preserved forms is so incomplete that we do not have either what must have been the

last step of the amphibian line or the first of the reptilian. The development of reptilian forms at the beginning and throughout the Permian time was most remarkable; it seems as if the conditions had been preparing for a long time and with the dawn of the Permian disappeared the last obstruction to the growth of the reptiles which appeared at once in the greatest profusion. Not only were there great numbers of forms, but they were, even in the earliest time that we know them, already highly specialized. The group that is discussed first, the *Parciasauria*, is nearest to the amphibia in many of its characters, while in others it is one of the most specialized of all the vertebrates. The Permian time has perhaps a larger number of highly and curiously specialized forms than any other time.

In 1840 there was discovered in the Karro formation, Permian or Permo-Triassic, of South Africa, a large number of fossil remains that were shipped to the British Museum, and there described by Professor Owen as a reptile closely related to the dinosaurs, and named by him, *Pareiasaurus bainii*. Later a nearly perfect skeleton was found and described by Professor Seeley, who redescribed the genus and species and placed it in a distinct order, the *Parciasauria* (1863). As this animal is typical of the whole group it may be described somewhat in detail.

Parciasaurus was one of the largest as well as one of the most amphibian-like of all the reptiles. The head was covered with large bony plates that had practically the same arrangement as in the *Labyrinthodontia;* the bones formed a complete roof, leaving only five openings in the skull, the orbits, nares, and the pineal foramen; there were traces of the sensory tracts on the surface of the skull, as in the largest of the *Labyrinthodonti;* the teeth were equal in size and distributed all around the edges of both jaws in an even series; there were small teeth arranged in rows on the palatine and the vomer bones in the roof of the mouth; the limbs were short and strong, with well-developed articular surfaces, and the feet were provided with strong claws; there were eighteen presacral vertebræ. This is of considerable

interest, as the number is the same that occurs in the turtles, and this is one of the few clues that we have as to the origin of the turtles. The vertebræ were biconcave, but were not perforated for the passage of the notochord, which was consequently divided into intervertebral segments. In the skin of the back directly over the spinal column there were developed three rows of bony ossicles, the middle row lying directly over the spinous processes and the other two lying upon each side; this development of dermal plates is regarded as the first step toward the formation of a carapace, and as an additional evidence of the connection of the *Pareiasauria* with the turtles. The thoracic girdle is stout and heavy and retains the central element, the interclavicle, which is lost in the majority of the reptiles; the pelvis was large and massive. In life the animal must have presented the appearance of a large amphibian; the legs were too short to lift the body off the ground, so the belly must have dragged as in the crocodiles; the whole body was short and squat and the tail was short; the skin was without scales and was probably thickened and folded.

Scattered bones indicate the presence of at least two other genera, *Propappus* and *Anthodus*, in the South African deposits, but not enough of the skeleton is known to warrant a description. In the American Permian deposits of Texas and Illinois there have been found a large number of forms belonging to this order; the best known are *Diadectes*, *Empedias*, *Chilonyx*, *Pantylus*, and *Pariotichus*.

Diadectes and *Empedias* are the best known of the forms; they are similar to *Pareiasaurus*, though they did not reach the size of that form; they had the same broad, flat skull with few openings; the teeth are different from the African form, in that, although they are similar in size and arranged in regular order around the edges, they are not simple in form, but are expanded laterally so that they exhibit broad grinding surfaces instead of cutting edges; they were undoubtedly herbivorous forms; the number of the presacral vertebræ is unknown, but it was probably greater than in *Pareiasaurus;* the verte-

bræ were greatly flattened in the antero-posterior direction and expanded laterally; this feature, with the short and stout limbs, led Cope to suggest that they were possibly fossorial in habit.

The three remaining forms mentioned have been placed in a separate family from the preceding, the *Pariotichidæ;* they are all smaller than *Diadectes*, never exceeding a length of two or three feet, and are further distinguished by the fact that the teeth are not equal in size in all parts of the jaw, the teeth of the middle part of the maxillary series being larger than the others. Certain of the less well known of the Texas forms show broad bony plates that extend outward from the middle of the back and cover the ribs to a large extent; they correspond to the ribs in number and position. This is a very close approximation to the condition in the turtles; in *Otocœlus* the plates are especially well developed and the lateral edges of adjacent plates meet.

The taxonomy of this group and its related forms is very imperfectly understood and there has resulted little but confusion from the numerous schemes of classification that have been proposed. When the first of the African fossils were discovered and described the name *Anomodontia* was proposed by Owen for the whole series of African forms, as he supposed that they were all closely related, but he soon recognized that this was not true and separated a group, the *Theriodontia*, to include the forms with a more carnivorous dentition. Later writers have found it necessary to depart very widely from this scheme and have founded new orders and in some cases done away with the original ones. Out of this tangle one thing seems very clear, the order *Parciasauria* is a distinct order separate from all the rest of the Permian reptiles and is the primitive form of all the reptiles. Other forms that are closely related to this order, but whose structure is too incompletely known to make the determination of their position definite, had best here be retained in the original order *Anomodontia* as suggested by Seeley and Lydekker. The classification of the forms will then stand as follows :

Order *Pareiasauria*.
Fam. *Pareiasauridae* (African forms).
Diadectidae (American forms).
Pariotichidae (American forms).
Elginidae (European forms).[1]
Order *Anomodontia*.
Suborder *Dicynodontia*.
Placodontia.
Theriodontia.

The *Dicynodontia*, including the genera *Dicynodon*, *Oudenodon*, and *Ptychosiagum* (*Ptychognathus*), are all from the same locality, South Africa, as *Pareiasaurus*, and from the same geological horizon.

Dicynodon is known only from the skull and is one of the most peculiar of the reptilian forms; the jaws were edentulous except for the presence of two large tusk-like teeth that grew out from the anterior part of the upper jaw just in the position occupied by the canine teeth in the mammals; the part of the upper jaw anterior to these teeth and the lower jaw were protected by a horny sheet similar to that present in the turtles; the posterior part of the skull was perforated by large fossae that served to lighten it considerably. This process of lightening the skull by the development of large fossae in the posterior, temporal portion, is a constant feature of all the reptiles above the *Pareiasauria* with the exception of the turtles. Many scattered bones have been found in the same deposits as the skulls of *Dicynodon* that may belong to the same genus, but there is not sufficient evidence to say definitely that this is true, and until the vertebral column and the limb bones are made out it

[1] *Elginia* is an imperfectly known form from the Elgin (Triassic) sandstones of Scotland. There are no bones preserved, but only the impression of the bones in the soft sandstone from which all the bony tissue has rotted out. The fossils were studied from casts made of the cavities left by the decayed bones. The animal was of considerable size, nearly as large as *Pareiasaurus* and the teeth were arranged in a regular series around the edges of the jaws; the appearance of the skull in life must have been most peculiar, the presence of strong rugosities on the surface of the bones of the skull show that the head was covered with large horns. *Geikia* was a related form from the same locality and horizon.

will be impossible to determine accurately their position with relation to the other reptiles.

Oudenodon was also described from the skull alone; the jaws are entirely edentulous and the appearance of the skull is strikingly testudinate. It has been suggested that this is the female of *Dicynodon*.

Ptychosiagum, or as it is more generally known, *Ptychognathus*, was very similar in many respects to the *Dicynodon*, having the same horny covering to the anterior portion of the jaws and the large canine teeth in the upper jaw; the peculiar part about the animal was the bending of the facial portion at almost a right angle to the upper surface of the skull and the upward extension of the anterior end of the lower jaw so that the mouth seemed to open on the superior face of the skull.

All of these animals must have been herbivorous; the large canine teeth were probably used to tear up the roots and aquatic plants upon which they fed. They could have been of no use as organs of offense or defense.

Placodontia.—These are rather problematical forms from the Muschelkalk (Triassic) of Germany. As in the case of the *Dicynodontia* the bones are all isolated and the various genera are known from the skulls; the few other bones that have been found in the same deposits may or may not belong with the skulls. Lydekker has called attention to the fact that all the bones that are found with the skulls are either dinosaurian or plesiosaurian; if it should turn out that the plesiosaurian bones belong with the skulls of the Placodontia it may be that that group belongs very far from the *Anomodontia* with which they are here placed, but until that is established it is perhaps best to take the evidence of the skull which points to a very decided relationship between the two groups. *Placodus* and *Cyamodus* are the two described genera.

Placodus was first described by Agassiz from a single tooth, and was regarded by him as a fish. The error was not corrected until the entire skull of the form was known. The skull was triangular in outline, very broad behind and rapidly narrowing

to a pointed rostrum in front; the orbits were large and the anterior nares very small; the posterior part of the skull shows the presence of the fossae already mentioned. The teeth are the most striking features of the skull, the anterior incisors were chisel-like and prehensile; the maxillaries were broad and flat; there were five on each side; besides the maxillary teeth there were three large palatine teeth on each side, so large that they covered nearly the whole roof of the mouth. The broad, low teeth of both this and the succeeding forms seem to indicate that the animals were accustomed to a molluscan diet.

Cyamodus was very similar to *Placodus*, but there were no prehensile incisor teeth and there were five palatine teeth, the posterior pair far exceeding the anterior ones in size.

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EDITORIAL.

IT would seem that there may be need to select for technical use suitable terms to specifically designate the critical factors of the sea border phenomena described in the first article of this issue. At least three agencies coöperate in producing a structural and topographic form which has a vital geologic function, and to which specific reference may frequently need to be made without descriptive circumlocution. The same may be said of some of the contributory factors and processes involved. The functions of these are more or less masked, and even antagonized, by adventitious phenomena which need to be distinguished and excluded. (1) There is first the building of the sediments into a submarine terrace. The plane toward which this terrace is built up is identical with that toward which the land is cut down. The two processes are complementary. The degradation of the one furnishes the material for the aggradation of the other, and their final result is a base-plain continuous with a terrace plain, both alike determined by the sea level. As the former process is called baseleveling, the latter might be designated base-terracing and the result a base-terrace, but these terms are not altogether felicitous, because *base* inevitably carries the idea of something beneath rather than above, and cannot perhaps easily be made to convey the conception of an overlying plain to which aggradation approaches, and in which it finds its summit limit. A happy term for a summit plain to which aggradation is limited just as degradation is limited to a base-plain does not as yet suggest itself. (2) There is next the cutting landward of the sea edge, whereby the sea shelf is extended at the expense of the land. This is essentially a baseleveling process, and as such perhaps needs no other term than baseleveling, except as qualifiers may occasionally be required to indicate the particular mode of its action. (3) Then there

is the lifting of the sea surface, whether by filling, by the spreading of the continent in its slow movement towards isostatic equilibrium, or by changes in the sea bottom. The effects in any case are essentially the same, and are world-wide by reason of the common level maintained by the ocean in all its parts. This sea lifting combines with and modifies both the terrace building and the shore cutting, and the common result is a shelf occupied by a shallow sea. This shelf is the great theater of sedimentation and of littoral life evolution. Its peculiar configuration, by giving great breadth to the shallow water circumcontinental seas upon a slight lifting of the sea level, or after the erosion and terrace building of prolonged quiescence, on the one hand, and by narrowing these shallow seas to mere fringing ribbons upon the drawing away of the sea until its shore stands against the abysmal edge of the shelf, on the other, makes it a vital factor in geological progress and gives occasion for a specific designation.

It is, however, desirable to exclude those areas that become submerged by their own individual movements and take on the similitude of submarine terraces without having any genetic or systematic relation to the sea level as such. They may stand at such depth as to give an expansion of shallow water just when the withdrawal of the sea narrows the shallow water tract on the true genetic shelf, and thus they may antagonize the evolutionary effects of the latter upon littoral life. They may, to be sure, coincide so nearly with the true shelf in position as to work concurrently with it and increase its effects, but this, from the nature of the case, will rather be the exception than the rule. Such adventitiously submerged portions of the continent must be regarded as factors that vitiate the ideal workings of the true sea-generated terrace.

Both the true sea-formed terrace and the continental border submerged by subsidence are at present embraced without distinction under the phrase "continental shelf"—a designation that fairly represents the topographic fact, but does not carry with it any specific idea of the diverse agencies involved in its

production or their opposed evolutionary functions. It does not discriminate between those features which are coöperative and world-wide, on the one hand, and those which are local and adventitious on the other.

Several terms are used tentatively in the indicated article to designate the true sea-generated terrace. Of these "circumcontinental terrace," "pericoastal terrace," and "peripheral terrace" are neither brief nor especially euphonious, and only partially imply the most important relationships of the formation. The term "sea shelf" is in many respects suitable, as it indicates the configuration, in a measure, and implies, or is susceptible of implying, adaptation to the reception of sediments and to the support of littoral life — the two most vital functions which it is desired to express; but it is not clear that the phrase is sufficiently different from the already adopted "continental shelf" to make it easy to develop a technical distinction in its usage. It has, however, the merit of implying a general and not a limited phenomenon, as is somewhat obscurely suggested in "continental shelf." This general sense is peculiarly appropriate, since the terrace is as universal (at least in its initial stages) as the sea border, and is a necessary consequence of the relations of sea and land. It may, perhaps, be best to use the universal term "sea shelf" for the true genetic phases of the submarine terrace, and to leave "continental shelf" to be used in its present undifferentiated application to the submerged border of a continent without regard to its specific genesis. But this suggestion is made with the most tentative intent.

The matter is here discussed not to propose a name for acceptance, but with the quite opposite purpose of filing a caveat in behalf of a free consideration of the merits of terms and a provisional use of them until experience shall bring into clear realization precisely what needs to be named and what terms best supply the need. The basal idea of the doctrine of multiple working hypotheses is applicable to nomenclature as well as geologic theory, and its use here is suggested. The subject is believed to have sufficient importance to justify it. T. C. C.

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.[1]

HOVEY,[2] in notes on the Isles of Shoals, of Maine and New Hampshire, states that the general rock constituting these isles is granitic, varying in color from white to black, and that this is cut by later dikes.

Hitchcock, C. H.,[3] gives a general account of the geology of New Hampshire, including a sketch of the work and conclusions of the first and second New Hampshire state surveys and of subsequent workers in the field. Some of the modifications indicated by work done since the close of the second state survey are: (1) Archean rocks exist as oval areas in the Stamford gneiss and south of Mt. Killington, Vt., in the Hinsdale, Mass., area, the Hoosac Mountain, and elsewhere. (2) The masses of Bethlehem gneiss are batholites, with inclusions of adjacent mica-schists. (3) A study of several areas of hornblende-schist proves that they are igneous.

Daly[4] discusses the porphyritic gneiss of New Hampshire, and concludes that it is an eruptive porphyritic granite, at least in its three most important areas, of post Devonian age.

Cushing[5] mentions pre-Cambrian rocks in Saranac township and Beekmantown, N. Y. These comprise gneisses and gabbro, upon which the Cambrian rests unconformably.

[1] Continued from page 756, Vol. IV., JOUR. GEOL.

The summaries of current pre-Cambrian literature which have heretofore been made by C. R. Van Hise will be continued by C. K. Leith.

[2] Geological notes on the Isles of Shoals, by H. C. HOVEY (Abstract): Proc. Am. Assoc. Adv. Sci., for 44th meeting, 1895, pp. 136, 137.

[3] The geology of New Hampshire, by C. H. HITCHCOCK: JOUR. GEOL., Vol. 4, 1896, pp. 44–62.

[4] Studies on the so-called Porphyritic Gneiss of New Hampshire, by R. A. DALY: JOUR. GEOL., Vol. 5, 1897, pp. 684–722, 776–794.

[5] Geology of Clinton county, N. Y. (preliminary), by H. P. CUSHING: Report of the State Geologist of New York for 1893, pp. 475–489.

Cushing[1] argues the existence of pre-Cambrian as well as post-Ordovician dikes in the Adirondacks and along Lake Champlain, offering the following reasons: (1) A much larger number of dikes occur in the pre-Cambrian than in the Paleozoic rocks. (2) A great proportion of the dikes are of diabase, while diabase rocks are not found outside of the pre-Cambrian areas. (3) Along the line of contact of the Potsdam with the older rocks north of the Adirondacks, the plentiful diabase dikes in the older rocks are apparently cut off by the Potsdam.

White[2] describes and maps the geology of Essex and Willsboro' townships, Essex county, N. Y. The Archean rocks of the townships comprise the following: (1) Labradorite rocks, gabbros, norites, and anorthosites, occupying the western half of the area, west of the Boquet River; (2) the metamorphic crystalline limestones and ophicalcites in the northeastern part of the area on Willsboro' Bay, and in the southeastern part of the area on the ridge of Split Rock Point; (3) gneisses and granites, chiefly on Split Rock Point. Following Adams,[3] all of these rocks are classed as Norian or Upper Laurentian.

Kemp[4] describes the geology of Essex county, N. Y. The pre-Cambrian succession in this county is as follows: (1) A gneissic series consisting of red and gray orthoclase gneisses, usually laminated, but at times rather massive. In these gneisses are the workable iron ores of the Adirondacks. (2) Apparently resting on (1), a series of crystalline limestones, ophicalcites, black hornblendic pyroxenic schists, and thinly laminated garnetiferous gneiss. Pegmatite veins are a frequent associate of these rocks. (3) A series of rocks of the gabbro family, ranging from aggregates of labradorite through

[1] On the existence of pre-Cambrian and post-Ordovician trap dikes in the Adirondacks, by H. P. CUSHING: Trans. N. Y. Acad. Sci., Vol. 15, 1896, pp. 248–252.

[2] The geology of Essex and Willsboro' townships, Essex county, N. Y., by T. G. WHITE: Trans. N. Y. Acad. Sci., Vol. 13, 1894, pp. 214–233, Pls. VI and VII.

[3] Ueber das Norian oder Ober-Laurentian von Canada, F. D. ADAMS: Neues Jahrb., B. B. VIII, p. 423.

[4] J. F. KEMP: Geology of Essex county (preliminary). Report of State Geologist of New York for 1893, pp. 433–472. See also The Geology of Moriah and Westport townships, Essex county, N. Y. Bull. N. Y. State Museum, Vol. 3, 1895, pp. 325–351. With a geological map.

varieties with increasing amounts of bisilicates to basic olivine gabbros. The gabbros vary from massive to gneissoid rocks which are difficult to discriminate from some of the gneisses of series 1. These rocks contain the titaniferous iron ores. They are intrusive in series 1 and 2. Resting unconformably upon 1, 2, and 3 is the Potsdam sandstone.

Kemp[1] describes the geology of the magnetites near Port Henry, N. Y., and especially those of Mineville in the Adirondacks of New York. The oldest rocks present in the district are quartzose gneisses and white crystalline limestones, with perhaps some more basic gneisses. The limestones appear to lie largely in the upper part of this group, but some of them are certainly below the other members. The acidic gneisses may have been granites or quartz-diorites. The gneiss and limestone group is cut by anorthosite intrusives, and both are in turn cut by gabbro intrusives. Trap dikes, usually of small width, are very common in this district. The age of these dikes is undetermined, but it seems probable that they may be of two ages, pre-Potsdam and post-Utica. Overlying unconformably all of the above described rocks is the Potsdam sandstone.

Darton[2] describes and maps the faulted region of Herkimer, Fulton, Montgomery, and Saratoga counties, New York. Laurentian rocks occupy the northern part of the area, forming the floor for a succession of sandstones, limestones, and shales, which dip to the south at a very moderate angle.

Kemp[3] describes the East River and Blackwell's Island section made by an underground tunnel at 70th street, New York City. Under the west channel is a fine grained mica-gneiss, containing pegmatite seams. Under Blackwell's Island and the adjacent waters is a gray gneiss. In the center of the east channel is a dolomite,

[1] The geology of the magnetites near Port Henry, N. Y., and especially those of Mineville, by J. F. KEMP: Trans. Am. Inst. Min. Engineers, Chicago meeting, Feb. 1897, p. 58.

[2] A preliminary description of the faulted region of Herkimer, Fulton, Montgomery, and Saratoga counties, by N. H. DARTON: 14th Ann. Rept. Geol. Survey of New York, for 1894, pp. 31–56, 1896. With geological map. Published in the 48th Ann. Rept. N. Y. State Museum, 1895.

[3] The geological section of the East River at 70th Street, New York, by J. F. KEMP: Trans. N. Y. Acad. Sci., Vol. 14, 1895, pp. 273–276.

which is flanked on the east side by mica-schist, locally pegmatized. Beyond the mica-schist on the Ravenswood shore is a massive hornblende-gneiss or granite, which is thought to be intrusive.

Merrill,[1] in connection with a report on the mineral resources of New York, publishes a geological map of the entire state and a large scale geological map of the southeastern part of the state. These maps embody information available to date concerning the distribution of the pre-Cambrian rocks of New York.

Merrill,[2] in connection with a report on road materials of New York, publishes a map of the state showing distribution of pre-Cambrian rocks.

Bascom[3] describes and maps pre-Cambrian volcanic rocks of South Mountain, Pennsylvania. The volcanic rocks are both basic and acid. The acid rocks comprise quartz-porphyries, devitrified rhyolites or aporhyolites, with accompanying pyroclastics, and sericite-schists, the last being the metamorphosed forms of the quartz-porphyries and aporhyolites. The basic rocks comprise melaphyres, augite-porphyrites, slates, and pyroclastics. Lithologically the volcanic rocks resemble the Keweenawan copper-bearing rocks of Lake Superior.

There is not sufficient evidence to decide the comparative age of the basic and acid rocks, but field observations in the Monterey district indicate that the acid rocks are the older. The volcanics are overlain, with stratigraphical unconformity, but with structural conformity, by sedimentary rocks of Lower Cambrian age. Both volcanics and sedimentaries have been subjected to strong dynamic action, whereby the igneous rocks have been cleaved and sheared, and the sedimentary rocks thrust over them from the east.

Kemp[4] describes the ore deposits at Franklin Furnace and Ogdensburg, N. J., and briefly sketches the general geology of the area. The

[1] Mineral resources of New York State, by F. J. H. MERRILL: Bull. N. Y. State Museum, Vol. 3, No. 15, 1895, pp. 365-595.

[2] Bull. N. Y. State Museum, Vol. 4, No. 17, 1897, pp. 90–134. With maps.

[3] The ancient volcanic rocks of South Mountain, Pa., by FLORENCE BASCOM: Bull. U. S. Geol. Surv., No. 136, 1896, pp. 124. With geol. map.

[4] The ore deposits at Franklin Furnace and Ogdensburg, N. J., by J. F. KEMP: Trans. N. Y. Acad. Sci., Vol. 13, 1893, pp. 76–98.

ore deposits occur in white crystalline limestone, which is cut in numerous places by dikes of granite, trap, and a rock taken to be altered gabbro. The white limestone is closely involved throughout its extent with a blue limestone of Cambrian or Cambro-Silurian age.

Wolff[1] briefly describes the eruptive rocks of Sussex county, New Jersey, with reference to their economic value. These include granite, elaeolite-syenite, elaeolite-porphyry, and camptonite, and are treated under the head of Archean.

Westgate[2] describes and maps the geology of the northern part of Jenny Jump Mountain, in Warren county, N. J. The main ridge of the mountain is formed chiefly of gneisses, comprising many varieties. These are, from northwest to southeast, and also, according to the banding, from base to top (1) granitoid-biotite-hornblende-gneiss, containing narrow bands of biotite-hornblende-gneiss; (2) hornblende-pyroxene-gneiss; (3) biotite-gneiss; (4) dark biotite-hornblende-gneiss; (5) granitoid-biotite-hornblende-gneiss; and (6) dark biotite-hornblende-gneiss, and gray micaceous gneiss. Certain of the dark hornblende-gneisses have been so extensively altered as to be called epidote rocks. The gneisses are in general granitoid and massive, and there is a conspicuous absence of schistose rocks and crumpling of the banding, the banding over wide areas having uniform strike and dip.

Along the southeast side of the mountain, at the northeast end of the mountain, and in two isolated outcrops within the gneisses of the main ridge, are areas of white crystalline limestone. The limestone is in all cases closely associated, and perhaps interbanded, with the dark biotite-hornblende-gneiss and gray micaceous gneiss (Nos. 4 and 6 above), and at the northeast end of the mountain also with quartz-pyroxene rock.

Cutting both gneisses and limestone are pegmatite, diabase, and amphibolite or granular diorite.

The origin and age of the gneisses are doubtful. The presence of limestone belts closely associated, and perhaps interbanded with the

[1] Report on Archean geology, by J. E. WOLFF: Ann. Rept. Geol. Surv. New Jersey, 1896, pp. 91–94. With map.

[2] The geology of the northern part of Jenny Jump Mountain, in Warren county, N. J., by LEWIS C. WESTGATE: Geol. Surv. of New Jersey, Ann. Rept. for 1895, pp 21–61, 1896. With geol. map.

hornblendic and micaceous gneisses, and the presence of magnetic iron ore, suggest a detrital origin for at least a part of the gneisses, and consequently their reference to the Algonkian. There may be really two series of rocks: (1) A series of limestone and associated interbedded rocks, of sedimentary origin, and (2) a series of more massive granitoid gneisses, probably older, and of unknown origin. This supposition is based only on the fact that the limestones are persistently associated with the hornblendic and micaceous gneisses and quartz-pyroxene rock, and are not found associated or in contact with the light colored granitoid gneisses which constitute the main mass of the mountain. However, there is not sufficient evidence to refer a a part of the gneisses to the Algonkian, and all are therefore classed as pre-Cambrian.

The crystalline limestones are believed to be distinct from and older than the blue magnesian limestone of Cambrian age, which occurs along the northwestern side of the New Jersey Highlands, and and which outcrops in isolated areas in the valleys adjacent to Jenny Jump Mountain, for the following reasons:

1. They differ lithologically from the blue limestone in being thoroughly crystalline, and in containing large amounts of accessory metamorphic minerals, showing that they have been subjected to general metamorphic forces of which the neighboring blue limestone shows no trace.

2. They occur in intimate association with the gneisses, which are of admitted pre-Cambrian age.

3. They show no intimate association in areal distribution with the blue limestone, nor any tendency to grade into it.

4. The metamorphic changes to which the white limestones have been subjected are general in their nature, and not due to the action of eruptives by which they are cut; so that no sufficient agent is at hand to account for the supposed change from blue into white limestone. The white crystalline limestones are therefore believed to be of pre-Cambrian age.

Williams and Clark[1] describe and map the geology and physical features of Maryland. The pre-Cambrian rocks, described by Williams,

[1] Geology and physical features of Maryland, by G. H. WILLIAMS and WM. B. CLARK: Extract from World's Fair Book on Maryland, Baltimore, 1893, pp. 1–67. With map.

form the eastern or holocrystalline division of the Piedmont Plateau region of Maryland, crossing the state in a general southwest direction from the southeast corner of Pennsylvania and the north end of Delaware. These rocks are but a part of the great crystalline plateau which extends from New York to Alabama along the eastern base of the Appalachians. Towards the east the pre-Cambrian rocks of Maryland plunge under Coastal Plain deposits, and toward the west they form the floor to support the Paleozoic strata of the Appalachians, reappearing in the granitic and volcanic rocks of South Mountain of Pennsylvania. The holocrystalline rocks are divisible into six types, three of which, gabbro, peridotite or pyroxenite, and granite, are of undoubted eruptive origin, and three of which, gneiss, marble, and quartz-schist, while showing no certain evidence of clastic structure, are believed to be sedimentary. The prevailing rock is gneiss, closely associated with marbles and quartz-schists, forming an intricate complex. The complex shows evidence of great dynamic action, the rocks, having been almost completely recrystallized. The eruptive rocks are all younger than the gneisses. The gabbro is the oldest, followed by the peridotite or pyroxenite, and the youngest is the granite. The granites are as a rule medium-grained biotite-granites, but they frequently take the form of pegmatite.

Williams[1] considers the general relations of the granitic rocks in the Middle Atlantic Piedmont Plateau and maps the same. The criteria by which ancient plutonic rocks in highly metamorphosed terranes may be recognized comprise radiating dikes, inclusions of fragments, contact zones, chemical composition, and petrographical structure. On these criteria it is concluded that most of the granitic rocks of Maryland are igneous, although many of them are changed to granite-gneiss, and of certain of these gneisses it cannot be asserted whether they are of aqueous or of igneous origin. South of Laurel, in the large area from Triadelphia southward to Brookville, at Murdoch Mill west of Washington, south of Falls Church in Fairfax county, Va., and at Cabin John Bridge on the Potomac River, there are gradations between granitic rocks and diorites or gabbros. In the Maryland

[1] General relations of the granitic rocks in the Middle Atlantic Piedmont Plateau, by GEORGE H. WILLIAMS. Introduction to Origin and Relations of Central Maryland Granites, C. R. KEYES, Fifteenth Ann. Rept., U. S. Geol. Surv., 1895, pp. 659-684, Pls. XXVII–XXXV.

rocks pegmatites are abundant. Some of these are, as indicated by their association with quartz veins and by parallel banding, water segregations. The majority, however, are igneous, as is shown by all of the phenomena of intrusive rocks.

Comments.—The description and discussion of the origin of the pegmatites are of great interest. From the descriptions it is clear, although Dr. Williams does not definitely say so, that there are nearly all gradations from material which is plainly a vein quartz deposit, through others where we have quartz and feldspar with a banded arrangement, and are water segregations, to the pegmatites which have distinct igneous characteristics. This region thus affords a beautiful illustration of Van Hise's[1] conclusion that under proper conditions water and liquid rock are miscible in all proportions, and that pegmatization comprises water impregnation, true igneous injection, and all intermediate processes.

Clark[2] describes the geology and physical features of Maryland. This account is essentially the same as that published by Williams and Clark[3] in 1893, and previously reviewed. Here, however, the crystalline rocks are classed as Archean and Algonkian, both of which are included under the general term Archean. The statement is made that there is no positive evidence that there are represented in Maryland rocks of the earliest portion of Archean time (meaning Archean proper), although a part of the gneiss complex may represent it. The Algonkian period, however, is represented by many varieties of rock. The rapidity with which the crystalline rocks furnished sediments for the overlying formations points to their high elevation in Archean time.

In the western division of the Piedmont Plateau region of Maryland, Algonkian rocks are present infolded with the Paleozoic deposits of Montgomery, Frederick, and Carroll counties. They consist of a single type resembling the metamorphosed basic volcanic rocks (Catoctin schist) of the Blue Ridge district.

[1] Principles of North American pre-Cambrian geology, by C. R. VAN HISE: 16th Ann. Rept. U. S. Geol. Surv., 1894–5 pp. 686–688.

[2] The physical features of Maryland, including the physiography, geology, and mineral resources, by WM. B. CLARK: Maryland Geol. Survey, preliminary publication of Vol. I, Pt. III, 1897, pp. 95. With map.

[3] Geology and Physical Features of Maryland, by G. H. WILLIAMS and WM. B. CLARK. Extract from World's Fair Book on Maryland; Baltimore, 1893.

Comments.—The use of the term *Archean* in two senses is objectionable. If it is used for all rocks older than the Cambrian, then another name should be applied to the basal complex. If, following the usage of the U. S. Geol. Survey, Archean is confined to the basal complex unconformably below the Algonkian, the general term for all rocks below the Cambrian should be *pre-Cambrian*.

Clark[1] describes the physical features and geology of Maryland, and gives a sketch of the development of knowledge concerning them. The description of pre-Cambrian geology is essentially the same as that given by Clark in a preliminary publication of this part of the volume,[2] and this in turn is but slightly different from an account given by Williams and Clark in 1893. Both of these articles are reviewed above. However, a few minor changes may be noted. The crystalline rocks of the Piedmont Plateau region, instead of being divided into six types as before, are divided, into seven typesdiorite being added to the list. Rocks of the Archean period are placed in the table of formations as doubtfully present.

Keyes[3] gives a detailed petrographical description of the Maryland granites. For reasons the same as given by Williams they are regarded as eruptive, and many of the gneisses are shown to be dynamically metamorphosed granites.

Darton[4] maps and describes the geology of the Fredericksburg sheet of Virginia and Maryland. He finds in the northwest and west parts that granite, gneiss, and schist occur, and in the northwest

[1] WM. B. CLARK: Outline of present knowledge of the physical features of Maryland, embracing an account of the physiography, geology, and mineral resources; Maryland Geol. Survey, Vol. I, Pt. III, 1897, pp. 139–228; Historical Sketch, Pt. II, *ibid.*, pp. 43–138. With map.

[2] The physical features of Maryland, preliminary publication of Vol. I, Pt. II, 1897.

Geology and physical features of Maryland, by G. H. WILLIAMS and WM. B. CLARK. Extract from World's Fair Book on Maryland; Baltimore, 1893.

[3] Origin and Relations of Central Maryland Granites, by C. R. KEYES, with an Introduction on the General Relations of the Granitic Rocks in the Middle Atlantic Piedmont Plateau, by G. H. WILLIAMS. Fifteenth Ann. Rep. U. S. Geol. Surv., 1895, pp. 685–740. Pls. XXXVI–XLVIII.

[4] Geol. Atlas of the U. S., Fredericksburg Folio, No. 13, by N. H. DARTON: U. S. Geol. Surv., Washington, 1894.

part of the area a belt of rock called the Quantico slate. This slate locally appears to grade into siliceous mica-schist or gneiss. It is about three-quarters of a mile in width, and strikes northeast and southwest. The granite, gneiss, and schist are regarded as pre-Cambrian. The slates resemble the roofing slates on James River, which carry Lower Silurian fossils.

Kimball[1] describes the magnetite belt at Cranberry, N. C., and indicates the mode of development of the magnetite. The ore belt occurs in the crystalline schists forming Cranberry Ridge. These schists are mostly basic, pyroxene and amphibole prevailing. It is suggested that they are of Algonkian age.

Keith[2] maps and describes the geology of the Knoxville quadrangle of Tennessee and North Carolina, and of the Loudon quadrangle of Tennessee. Ocoee rocks form the mountain areas. From the base upward the series comprises the Wilhite slate, the Citico conglomerate, the Pigeon slate, the Cades conglomerate, the Thunderhead conglomerate, the Hazel slate, and the Clingman conglomerate.

The Wilhite slate is bluish-gray or black argillaceous slate. In its upper portion it becomes calcareous, and contains frequent beds of limestone and limestone conglomerate. The thickness is ordinarily from 300 to 400 feet. The Citico conglomerate is entirely siliceous, and varies from fine white sandstone to coarse quartz conglomerate, with a few thin beds of sandy shale. The Pigeon slate is mainly an argillaceous slate of great uniformity, occasionally banded by thin seams of coarser siliceous material. The thickness varies from 1300 to 1700 feet.

The Cades conglomerate, the Thunderhead conglomerate, the Hazel slate, and the Clingman conglomerate, are not described for the Loudon quadrangle.

For the Knoxville quadrangle the Cades conglomerate consists of thick beds of slate, sandstone, graywacke, and conglomerate. The

[1] The magnetite belt of Cranberry, N. C., by J. P. KIMBALL: Am. Geol., Vol. 20, 1897, pp. 299-312.

[2] Geol. Atlas of the U. S., Knoxville folio, No. 16, by ARTHUR KEITH: U. S., Geol. Surv., Washington, 1895.

Ibid., London folio, No. 25, 1896.

apparent thickness is 2400 feet, and this may be an overestimate, because the formation may be repeated by folding. The Thunderhead conglomerate consists of a series of conglomerates, graywackes, and sandstones, with many small beds of slate. The thickness is believed to be about 3000 feet. The Hazel slate is chiefly a black slate, but it contains many thin beds of sandstone and conglomerate in small quantity. The exact thickness cannot be ascertained, but it is believed to be about 700 feet. The Clingman conglomerate is the same in composition as the Thunderhead conglomerate, except that in the Clingman conglomerate there is smaller development of slate beds.

The age of the Ocoee rocks is undetermined, and they are therefore mapped as of unknown age.

Hayes[1] maps and describes the geology of the Cleveland quadrangle of Tennessee. Ocoee rocks occupy the southeastern part of the quadrangle, forming Big Frog Mountain and the plateau along its western base. No fossils have yet been found in these rocks, and they are separated by a great fault from rocks of known age, so that their position in the stratigraphic column cannot be fixed with certainty, but since they bear the marks of extreme age, they are considered as probably Algonkian. The Ocoee series comprises in this area the following formations, from the base upward: the Wilhite slate, the Citico conglomerate, the Pigeon slate, and the Thunderhead conglomerate and slate. Their correlation with formations bearing the same names in the Knoxville quadrangle to the northeast, described by Keith, is only approximate. The Wilhite slate consist in the main of dark blue or black slate. The Citico conglomerate varies from a coarse, massive conglomerate to fine grained sandstone or quartzite in sandy shale. The thickness varies from 500 to 1150 or more feet. The Pigeon slate resembles the Wilhite slate, the chief difference being a frequently observed banding and an abundance of interbedded gray schistose sandstones and graywackes, and occasional conglomerates. The Thunderhead conglomerate and slate can be separated into three divisions. The lowest of these, from 800 to 1000 feet thick, is a massively bedded conglomerate, made up largely of blue quartz and feldspar pebbles. The middle division consists of interbedded black slate and schistose conglomerate or sandstone, the slate apparently

[1] Geol. Atlas of the U. S., Cleveland folio, No. 20, by C. W. HAYES: U. S. Geol. Surv., Washington, 1895.

predominating. The upper division is also composed of conglomerate and slate, but the slate is comparatively unimportant.

King[1] describes the geology of the "Crystalline Belt" of Georgia, in connection with the occurrence of corundum. The Crystalline Belt occupies an area of 12,430 square miles, crossing the northern part of Georgia from the northeast to the southwest, and lying between Paleozoic strata in the northwest corner of the state, and Mesozoic and Cenozoic strata in the southern half of the state.

The rocks of the Crystalline Belt are divisable into two petrographical classes. The first consists of a series of mica-schists, slates, shales, conglomerate, and marble, which, though more or less crystalline, show evidence of clastic character. This class is called the *semicrystalline* series. The semicrystalline rocks are confined to an area bordering the Paleozoic to the northwest. The second class comprises eight types of rock. Three of them, limestone, quartzite, and slate, are undoubtedly clastic; three of them, granite, gneiss, and mica-schist, are completely crystalline and show no trace of clastic character; and two, peridotite, and diorite, are presumably of eruptive origin. Gneiss and mica-schist are the prevailing rocks. This second class is termed the *holocrystalline* series.

The rocks of the Crystalline Belt are separated from the Paleozoics on the northwest by a strong unconformity. Between the semicrystalline and holocrystalline rocks there is apparent transition.

Throughout the Crystalline Belt there is a uniform dip to the southeast, pointing toward a moving force from the southeast, but in the holo-crystalline area the dip is much steeper than in the semicrystalline area. Disturbances and alterations are more extensive in the holocrystalline rocks than in the semicrystalline rocks. Corundum is present only in the holocrystalline rocks.

From these facts it is believed that the holocrystalline area is older than the semicrystalline area, and formed the continent against which washed the waters of the sea which deposited the rocks of the semicrystalline series. While a portion of the holocrystalline series may be Archean, because of the presence in it of undoubted clastics the series is referred to the Algonkian. The same reference is made for the semicrystalline rocks.

[1] Corundum deposits of Georgia, Chap. iv, Geology of the Crystalline Belt, by FRANCIS P. KING: Bull. Geol. Surv. of Georgia, No. 2, 1894, pp. 58–72.

The history, varieties, and characters of corundum, and its mode of occurrence in the holocrystalline rocks, are fully described.

Smith[1] gives a general account of the character, distribution, and structure of the crystalline rocks of Alabama. The rocks are altered sedimentary and igneous rocks. The altered sedimentary rocks, called the Talledega or Ocoee series, is referred to the Algonkian, and the altered igneous rocks are referred to the Archean.

The Talledega series is found in the northeastern part of the state, in four or five roughly parallel belts, running northeast and southwest, the strata in general dipping to the southeast. The series comprises, in order of abundance, clay-slates or argillites, in places impregnated with graphite, quartzites and quartzite conglomerates, and crystalline limestones or dolomites. The slates, quartzites, and conglomerates resemble very strongly certain strata of undoubted Cambrian age, and it is probable that some of the strata included with the Talledega are altered Cambrian rocks. As yet, however, no fossils have been discovered in them.

The altered igneous rocks occur in three main belts roughly parallel with the sedimentary belts in the northeastern part of the state. In order of abundance they are gneisses and mica-schists, cut by dikes of granite, diorite, and various hornblendic, pyroxenic, and chrysolitic rocks.

Gold ores are associated with both the sedimentary and igneous series. Their mode of occurrence is briefly sketched.

Brooks,[2] in petrographical notes on some metamorphic rocks from Alabama, makes general statements concerning the geology of the metamorphic rocks of Alabama and Georgia. The metamorphic rocks of Alabama and Georgia may be differentiated into two series. The older, or crystalline series, includes crystalline schists and gneisses, whose origin is doubtful, together with large masses of gneissoid granite. The younger, or clastic series, is typically made up of phyllites, sericite-schists, chlorite-schists, conglomerates, quartzites, crystal-

[1] A general account of the character, distribution, and structure of the crystalline rocks of Alabama, and of the mode of occurrence of the gold ores, by E. A. SMITH: Bull. Geol. Surv. of Alabama, No. 5, 1896, pp. 108–130.

[2] Preliminary petrographic notes on some metamorphic rocks from Eastern Alabama, by A. H. BROOKS: Bull. Geol. Surv. of Alabama, No. 5, 1896, pp. 177–197,

line sandstones, and in a portion of the region limestones and marbles. The rocks of both series are closely associated with rocks of undoubted igneous origin.

Clements[1] gives notes on the microscopical character of certain rocks from the crystalline area of northeastern Alabama. The rocks include sedimentary and igneous rocks, and others whose origin is unknown. The sedimentary rocks are comparatively unimportant. Disregarding the sedimentary rocks, the rocks as a whole have the characters of Archean rocks.

Hawes[2] gives notes on the microscopical characters of the Alabama crystalline or metamorphic rocks.

Darton,[3] in connection with a discussion of artesian well prospects in the Atlantic Coastal Plain region, briefly describes the occurrence of the crystalline rocks. The crystalline rocks, predominantly granite and gneiss, outcrop along a line which passes from New York City through Philadelphia, Baltimore, Richmond, Weldon, and Columbia, to Augusta, Ga., and thence through Georgia and Alabama. Westward they extend up the gentle slope of the Piedmont Plateau to the base of the Appalachians. To the east they dip below unconsolidated sedimentaries, and along the ocean shore, from New Jersey south, they are 2000 feet below the surface.

GENERAL COMMENTS.

As yet the broader structural problems of the crystalline and semi-crystalline rocks of the Appalachian region and the Piedmont Plateau are far from completely solved. It is certain that some of the semi-crystalline rocks which in former years have been called Algonkian or Archean are Paleozoic. It seems equally certain that in the Appalachian and Piedmont Plateau region are greatly metamorphosed sedi-

[1] Notes on the microscopical character of certain rocks from Northeast Alabama, by J. MORGAN CLEMENTS: Bull. Geol. Surv. of Alabama, No. 5, 1896, pp. 133–176.

[2] Notes on the microscopic characters of the Alabama crystalline or metamorphic rocks, by G. W. HAWES: Bull. Geol. Surv. of Alabama, No. 5, 1896, pp. 131–132.

[3] Artesian well prospects in the Atlantic Coastal Plain region, by N. H. DARTON.: Bull. U. S. Geol. Surv., No. 138, 1896, pp. 18–19.

mentary rocks, many of them being completely crystalline schists and gneisses, which are of pre-Paleozoic age. Further, in this region is a great series of sedimentary rocks known as the Ocoee series, the position of which is not determined, but which may include both Paleozoic and pre-Paleozoic rocks. Apparently all of the series of sedimentary rocks thus far mentioned rest unconformably upon a still older granite-gneiss-schist complex. It therefore appears clear that there are at least three series of rocks represented in the Appalachian region and the Piedmont Plateau, and there may be more.

Until the great structural problems of the Appalachian and Piedmont Plateau region are settled, the only safe course is to call pre-Paleozoic the rocks which are certainly below the Paleozoic, leaving open the question of their further classification as Archean or Algonkian. In the case of the Ocoee, at the present time, the series cannot be placed even as closely as pre-Paleozoic. In work in Maryland, North Carolina, Tennessee, Alabama, and Georgia, as shown by the above summaries, this plan in some cases has not been followed, but rocks supposed to be of pre-Paleozoic age have been somewhat arbitrarily assigned to the Archean or Algonkian. The use of these names, without definite knowledge of the structural features as a basis for the reference, is a hindrance rather than a help to further classificatory work. When the age of a series in the region is more definitely determined, the rocks can be placed as Algonkian or Archean without contradicting previous statements. C. K. LEITH.

Reviews.

United States Geologic Atlas, Folio 42, Bidwell Bar, California. 1898.

This folio consists of six pages of text, signed by H. W. Turner, geologist, a topographic map of the district, a map showing the areal geology, and a map showing the economic features, with one page of special illustrations. The quadrangle represented in this folio lies between the parallels 39° 30′ and 40° north latitude and 121° 30′ and 121° west longitude. It comprises a portion of the northern Sierra Nevada and lies chiefly in Plumas and Butte counties. Except a small area in the southwest corner, the quadrangle is drained entirely by the Feather River. As in the other Gold Belt folios, the formations are divided into two main groups: The Bed Rock series, and the Superjacent series.

Bed Rock series.— In this quadrangle the Bed Rock series is comprised very largly of old igneous rocks with minor amounts of Palæozic sediments. In the northeast corner a single belt of slates, known to be of Juratrias age, is noted. The age of the Palæozoic rocks is known to be in part Carboniferous. In the Diadem lode there occur silicified tests of foraminifera, *Loftusia columbiana* Dawson, this being the first time this fossil has been found in California. Its age is Carboniferous. Other Carboniferous fossils were found at other points in the Calaveras formation. The igneous rocks belonging to the Bed Rock series may be grouped under three main headings:

1. Amphibolite and amphibolite schists, diorite and porphyrite. In all of the rocks of this series, excepting some of the porphyrite, there is a large amount of green aluminous amphibole. The main mass of the rocks of this group are metamorphic lavas and tuffs.

2. Magnesian rocks, comprising serpentine, talc, chlorite and colorless amphibole rocks, all of which appear to be merely different alteration products of rocks of the peridotite and pyroxenite family. The serpentine has resulted from the alteration of facies of the magma rich in olivine and rhombic pyroxene, and the talc, chlorite and colorless amphibole schists from other facies rich in aluminous pyroxene. The

colorless amphibole comprises probably both edenite and gedrite. The magnesian rocks above described are cut by soda-feldspar dikes, which appear to have a genetic connection with the peridotite-pyroxenite magma.

3. Granular intrusive rocks, mostly acid in character, including granite, granodiorite, quartz-diorite and gabbro. All of the granitic rocks are cut by dikes of aplite, which is regarded as the residual acid material of the magma squeezed up into cracks after the consolidation of the granitic rock; and by dikes of a fine grained diorite, which usually contains idiomorphic needles of brown amphibole. The occurrence of these fine grained diorites or diorite porphyries in small dikes at widely separated intervals in the Sierra Nevada, suggests that they are the differentiation product of some other magma. These dike rocks are very similar in mineral and chemical composition at widely separated localities, and appear to be among the latest of the pre-Cretaceous intrusives, inasmuch as the dikes cut nearly all the pre-Cretaceous rocks. It does not seem possible to ascribe the origin of these dikes to a batholithic magma, underlying the range, inasmuch as the rock occurs almost nowhere in masses sufficiently large to be represented as areas on the geological maps. A genetic connection with the great granodiorite batholith underlying the Sierra Nevada, is suggested by the field relations of this diorite-porphyry.

Superjacent series.— The rocks of the Superjacent series in the Bidwell Bar quadrangle consist almost entirely of gravels and Tertiary lavas, and tuffs. During the Neocene period the Bidwell Bar quadrangle was a country of low relief, as were other portions of the Gold Belt. The Auriferous river gravels formation represents deposits made by the rivers of the Neocene period. These are very largely covered at the present time by lavas. While volcanic rocks are very abundant, there appears to have been few volcanoes in the district. The lavas come chiefly from vents located in the Downieville quadrangle, which lies just east. This is not true, however, of the lavas of the plateau west of the north fork of the Feather. These originated in the Lassen Peak volcanic area.

West of Franklin Hill is the base of a former volcano. The Superjacent volcanic rocks are grouped under the following heads:

Basalt:

Older basalt, with litle olivine.

Later basalt, dark colored and rich in olivine.

Andesite :

Hornblende-andesite, tuff or breccia.

Fine grained hypersthene-andesite.

South of Campbell Peak in the canyon of Fall River, is a dike-like mass of fragmental andesite. This is exposed in the bed of the river, and it extends vertically up the sides of the canyon. In the dike material are embedded the fragments of fossil wood (sequoia) It is clear that this dike represents a fissure opened by an earthquake (?) and filled in by the fragmental andesite from above.

Meadow Valley in the northeast corner represents a depressed area, the result of faulting in early Pleistocene time. During a portion of the Pleistocene, this valley was occupied by a lake.

On the northeast slope of Spanish Peak ridge are fine moraines, and evidences of glacial action were found also at many other points. The lowest elevation which sheltered on its north slope a glacier during the glacial period, is the ridge southwest of Buck's Valley. At one point what appeared to be a morainal pond had been formed by a small glacier. The top of the ridge south of this pond has an elevation of only 5800 feet. As a general rule it may be said that in the Sierra Nevada, all those slopes which now shelter snow banks during the entire season, nourished glaciers during the glacial period.

Structure.— A figure is introduced into the text, showing the general parallelism of the schistosity to the granitic masses, which represent intrusions into the schistose rocks. It will be noted, however, that narrow tongues of the granitic rocks at some points cut directly across the schistosity, and it appears probable that the schistosity in the main was developed at a period antecedent to the granitic intrusions and that the parallelism of the lines of schistosity to the contact of the entering granite, is due to these masses being forced aside by the intrusive rock, the separation of the schistose masses taking place most readily parallel to the schistosity. There is evidence of faulting on an extensive scale in the northeast portion of the quadrangle to the east of Spanish Peak, and faulting was noted at the head of Dogwood Creek. A photograph of this fault scarp is reproduced on the illustrations sheet.

Economic geology.— The economic features of the district include a description of the gold vein deposits, and of manganese, iron, chromite and lime and marble deposits. While quartz is the ordinary vein material of the gold deposits, one instance of an auriferous barite vein is noted.

North Carolina Geological Survey. J. A. HOLMES, State Geologist, Bull. 13; Clay Deposits and Clay Industry in North Carolina, by HEINRICH REIS.

There are few things more noticeable and at the same time more gratifying in the recent work of the state geological surveys than the increased attention paid to the economic and industrial portion of the work. So long as it remains necessary to justify the existence of surveys to appropriation committees, it will remain pleasant to point to practical work and direct economic returns in neighboring states. It has been abundantly shown that legislators do not usually object to paying for a reasonable amount of purely scientific investigation, provided only that the practical work waiting to be done be not slighted. It is equally well demonstrated that it is only by conducting work along lines of both pure and applied science that state surveys attain their highest usefulness. They do better work and gain more quickly and hold more securely the confidence of those who pay for this work. Neglect of these truisms has led to the premature cutting off of more than one survey. It is pleasant, accordingly, to note that the reports coming from North Carolina are not only scientific in their accuracy, but practical in their scope. Such a paper as the one under review, by stimulating the development, and, in a sense, advertising the clay resources of the state, must inevitably be followed by direct material benefits. The care taken by the author to suggest changes and improvements in present treatment as well as to note lines of expansion, in view of his wide experience with clays, are exceedingly valuable.

The paper opens with a brief statement of the origin of clays, and a classification of those developed in North Carolina. This is followed by a clear, though condensed, discussion of the chemical and physical properties of clays and of the geography and geology of the North Carolina deposits. The kaolin or china clays, pottery clays, fire clays, pipe clays, and brick clays are then discussed briefly with reference to distribution, character and proper treatment. A large number of analyses and tests have been made, and are not only inserted, but are interpreted. To persons outside the state the chapter devoted to the kaolins will naturally attract the most attention, since it is kaolin from North Carolina which figures so largely in the pottery industry of the whole country. Judging from certain facts brought out in the report the time may come when the kaolin will be extensively used in its

home state. There will, however, be many matters to consider before the attempt is made. The present, being a preliminary report, leaves this as well as many interesting problems of cost, production, markets, and treatment almost untouched. We would like, for example, to know more about the fuel and labor costs, the type of dry houses and speed of drying found best adapted to the various clays, methods of burning, length of water-soaking, and many other things. These will, of course, be discussed in the final report, which will be eagerly anticipated by all interested in the clay industry.

Among the most valuable things in the present paper are the rational analyses and the large number of physical tests. The latter include the determination of the percentage of water necessary to give a workable paste, the approximate plasticity, the speed of slaking, texture, percentage of air and fire shrinkage, average and maximum tensile strength per square inch, the point of vitrification, vitrification and viscosity temperatures, total fluxes, color when burned, and specific gravity. There is nothing new or especially accurate with regard to the plasticity determinations, such general expressions as "lean," "fair," "good," etc., being used. It is not stated how many tests were used in getting the average tensile strength, nor is the range of variation given. In view of the method adopted, a minor variation from the standard cement test, the omission is important. For example, the pottery clay (No. 50) from Blackburn in Catawba county, gave an average tensile strength of 148 pounds, with a maximum of 200 pounds per square inch. Assuming that the minimum varied as much from the average as the maximum, and we have as the result a clay with tensile strength varying from 96 to 200 pounds, over 100 per cent. While some of the figures are closer, this is not exceptional except in the high strength. Other variations are 84 average to 120 maximum, 60 to 81, 14 to 16, 15 to 18, etc. In short, the results, judging from the imperfect data presented, show as wide or wider variation than is common in cements, and there is the same need here for an improved and more accurate test that cement users recognize. It would be interesting to know more also as to the methods adopted in making some of the tests. For example, does the percentage of water necessary to give a workable paste have reference to clays dried to a uniform state or taken from the bank? The difference might be considerable. Was the shrinkage measured in bulk on market products or along single directions on tests bricklets? Without this data the

results are somewhat less valuable for general comparison, though still of great importance. As a whole the report is to be highly commended. It is concise and fresh. It tells not only about North Carolina clays, but incidentally it gives the point of view of the modern student of clays. While no new methods are developed, there are no modern methods of value which have been overlooked. In addition to its other excellent features the paper is well printed and sufficiently illustrated. H. F. BAIN.

Lehrbuch der praktischen Geologie. Arbeits- und Untersuchungsmethoden auf dem Gebiete der Geologie, Mineralogie, und Paleontologie. Von DR. KONRAD KEILHACK, Kgl. preuss. Landsgeologen in Berlin. 639 pp. Stuttgart, 1896.

The title of this book fairly indicates its scope. It is essentially an exposition of the results to be sought in the field, and in the laboratory study of the materials gathered in the field, and of the methods by which these results are attained. It is the only book with which we are familiar which essays to deal with so comprehensive a subject. Geikie's *Outlines of Field Geology* covers in a briefer way some part of the ground of the present volume. Richtofen's *Führer für Forschungsreisende* gives many suggestions along the same lines. Nevertheless the present volume is so much more comprehensive than anything else which has been written on the subject that it may fairly be said to be without a rival.

Formidable as was the task which the author set for himself in the preparation of this work, it must be said to have been well done. Probably no two geologists would give instructions for the same work in the same way, and no one could be expected to make a treatise on so broad a subject equally satisfactory in all its parts; yet with all the exceptions which might be taken to the order or method of treatment, and with all the shortcomings which specialists in this department or that might point out (and they are neither numerous nor serious), the book might be read with profit by every geologist in the early stages of his work, and many parts of it by men who are no longer novices. The volume is naturally more satisfactory in those departments of geology where study has been longest prosecuted, and where methods and principles have become most firmly established; for example, the

sedimentary fossiliferous rocks. It is less satisfactory (chiefly because of its brevity) in its discussion of the methods applicable to metamorphic rocks, and to formations which are not indurated, and which contain no fossils, such as the drift and the late Tertiary and Pleistocene formations outside the drift-covered areas. Adequate directions for detailed work in these departments of geology would perhaps have carried the author beyond the limits of a volume intended primarily for those who are beginning practical work in geology, and for the intelligent reader who seeks to understand the nature of the work which geologists have to do and the results to which their work leads.

The criticism might be made that at some points the book goes into too great detail. Here and there specifications are given which any student who has had even fairly adequate instruction does not need. If the author intended to make the book so complete that it might be of service even to those who have not had adequate instruction, these details are in place; but for young geologists who have had the teaching which most young men who enter the profession in our country have had, some of the simpler matters might have been omitted.

The volume is so helpful in many ways that teachers of geology would do well to encourage its study by students who expect to make geology a special study. R. D. S.

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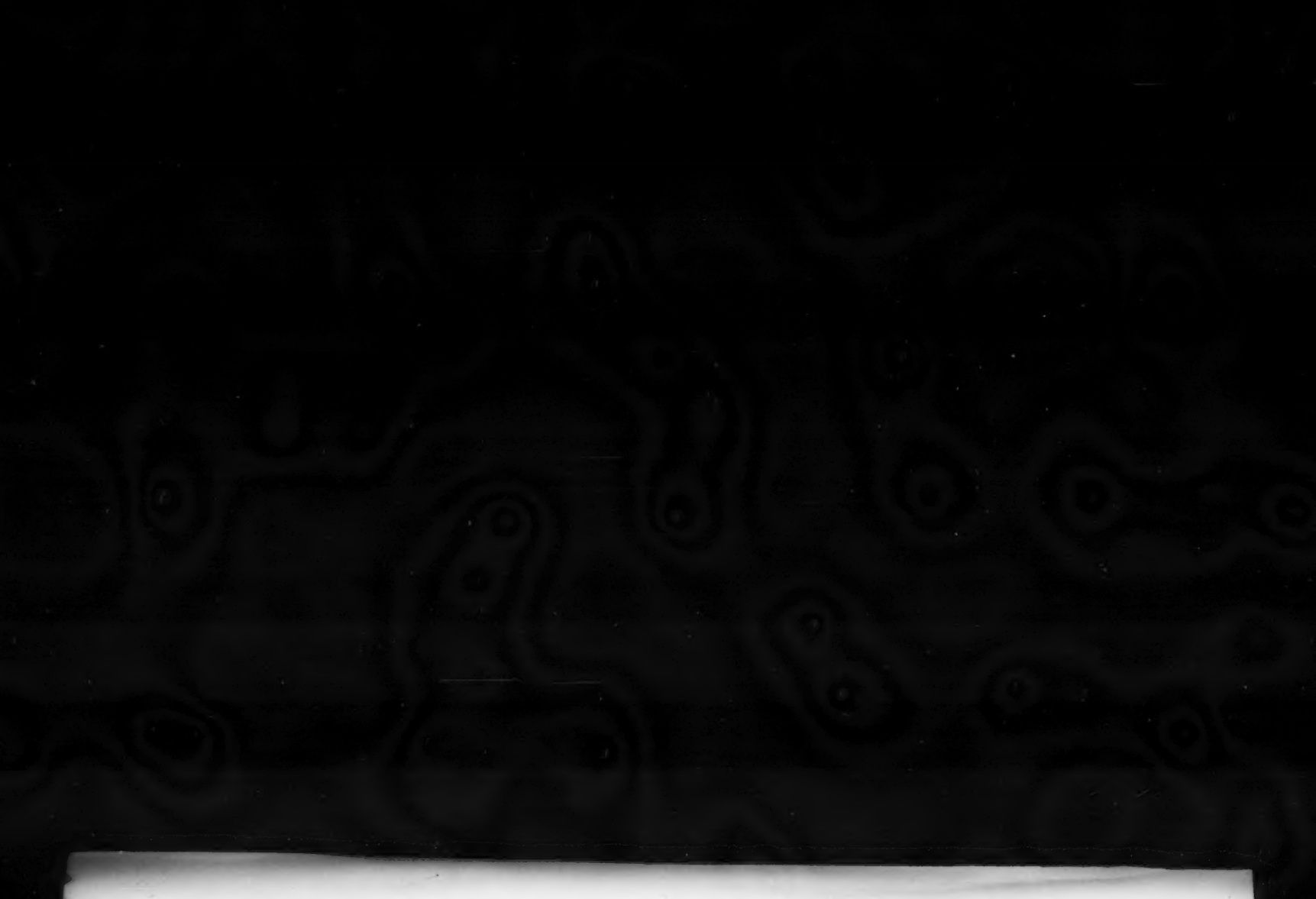
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